Chapter 2
Foundations of Complex Behavioral Economics

2.1 Overview

Herbert A. Simon developed the idea of *bounded rationality* from his earliest works (Simon 1947, 1955a, 1957), which is viewed as the foundation of modern *behavioral economics*. Behavioral economics contrasts with more conventional economics in not assuming full information rationality on the part of economic agents in their behavior. In this regard, it draws on insights regarding human behavior from other social science disciplines such as psychology and sociology, among others. Without question, one can find earlier economists who argued that people are motivated by more than mere selfish maximization. Indeed, from the very beginnings of economics with Aristotle, who put economic considerations into a context of moral philosophy and proper conduct, through the father of political economy, Adam Smith in his *Theory of Moral Sentiments* (1759), to later institutional economists such as Thorstein Veblen (1899) and Karl Polanyi (1944) who saw peoples' economic conduct as embedded within broader social and political contexts. Nevertheless, it was Simon who coined both of these terms and established modern behavioral economics.

Simon's initiatives led to a flurry of activity and research over the next few decades, much of which became more influential in business schools and management programs as the rational expectations revolution conquered most of economics during the 1970s and 1980s. Assuming bounded rationality by economic agents led him to the concept of *satisficing*, that while people do not maximize they strive to achieve set goals within constraints. This became accepted in business schools as managers were taught to achieve levels of profit acceptable to owners.

Also arising out of his discovery of bounded rationality was his interest in pursuing more deeply how people think and understand as part of their making decisions. This led him to consider how this could be studied through the use of computers. This led him to become one of the founders of the field of *artificial intelligence* (Simon 1969), and Simon more generally is regarded as one of the early

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leaders of computer science more generally. But it was his concern regarding the implications of bounded rationality that led him into this nascent field.

Simon would also become a leading figure in the early development of complexity theory, particularly of hierarchical complexity theory (Simon 1962), although he only made an indirect link between this and bounded rationality. However, modern complexity theorists are much more willing to see a close and direct link between complexity of one sort or another and bounded rationality, and thus also with behavioral economics (Velupillai 2019).[1] Indeed, complexity can be seen as a, if not the, fundamental foundation for why people have bounded rationality. Complexity lies at the very heart of behavioral economics in this view, and Simon sought to understand how people decide in the face of such ineluctable complexity.

2.2 Herbert Simon and Bounded Rationality

The late Herbert A. Simon is widely considered to be the father of *modern behavioral economics*, at least it was his work to which this phrase was first applied. He was also an early theorist of complexity economics, if not the father per se, and also was one of the founders of the study of artificial intelligence in computer science. Indeed, he was a polymath who published well over 900 academic papers in numerous disciplines, and while he won the Nobel Prize in economics in 1978 for his development of the concept of *bounded rationality*, his PhD was in public admnistration and he was never in a department of economics. We must use the term "modern" before "behavioral economics" because quite a few earlier economists can be seen as focusing on actual human behavior while assuming that people do not behave fully in what we would now call an "economically rational" manner (Smith 1759; Veblen 1899).

We must at this point be clear that by "behavioral economics" we are not assuming a view similar to that of "behavioral psychology" of the sort advocated or practiced by Pavlov or B.F. Skinner (1938). The latter does not view studying what is in peoples' minds or consciousness as of any use or interest. All that matters is how they behave, particularly how they respond to respond to repeated stimuli in their behavior. This is more akin to standard neoclassical economics, which also purports to study how people behave with little interest in what is going on inside their heads. The main difference between these two is that conventional economics makes a strong assumption about what is going on inside peoples' heads: that they are rationally maximizing individual utility functions derived from their preferences using full information. In contrast, behavioral economics does not assume that

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[1] Problems arising from dynamic complexity such as sudden discontinuities and sensitive dependence on initial conditions imply extreme difficulty for agents to form rational expectations regarding future events, much less full information and complete rationality in their decisionmaking. Another source of bias is the time inconsistency implied by hyperbolic discounting (Gowdy et al. 2013).

people are fully rational and particularly does not assume that they are fully informed. What is going on inside their heads is important, and such subjects as *happiness economics* (Easterlin 2017) are legitimate topics for behavioral economics.

In any case, from the beginning of his research with his path-breaking PhD dissertation that came out as a book in 1947, *Administrative Behavior* and on through important articles and books in the 1950s (Simon 1955a, 1957), Simon saw people as being limited in both their knowledge of facts as well as in their ability to compute and solve the difficult problems associated with calculating optimal solutions to problems. They face unavoidable limits to their ability to make fully rational decisions. Thus, people live in a world of *bounded rationality*,[2] and it was this realization that led him into the study of artificial intelligence in computer science as part of his study of how people think in such a world (Simon 1969).

This led Simon to the concept of *satisficing*. People set targets that they seek to achieve and then do not pursue further efforts to improve situations once these targets have been reached, if they are. Thus a firm will not maximize profits, but its managers will seek to achieve an acceptable level of profits that will keep owners sufficiently happy. This idea of satisficing became the central key to the behavioral study of the firm (Cyert and March 1963) and entered into the management literature, where it probably became more influential than it was in economics, for quite a long time.

Some economists, notably Stigler (1961), have taken Simon's position and argued that he is actually a supporter of full economic rationality, but only adding another matter to be optimized, namely minimizing the costs of information. People are still optimizing but take account of the costs of information. However, Stigler's argument faces an unavoidable and ineluctable problem: people do not and cannot know what the full costs of information are. In this regard they face a potential problem of infinite regress (Conlisk 1996). In order to learn the costs of information, they must determine how much time they should spend in this process of learning; they must learn what the costs of learning what the costs of information are. This then leads to the next higher order problem of learning what the costs of learning what the costs of information are, and there is no end to this regress in principle.[3] In the end they must use the sorts of *heuristic* (or "rule of thumb") devices that Simon proposes that people facing bounded rationality must use in order to answer the question. Full rationality is impossible, and the ubiquity of complexity is a central reason why this is the case.

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[2] Arguably Simon was parallel on this with Broadbent (1950), who initiated studies of how limits on cognition lead to workload fatigue.

[3] Central planners faced this problem in how much time and how they spend thinking about how to plan. In the French and Russian literature this came to be known as *planification*, the process of "planning how to plan," although this term was sometimes used for planning in general as well as for dealing with the problem of aggregating micro level plans into coherent macro ones (Rosser Jr. and Rosser, 2018, p. 11).

Simon (1976) distinguishes *substantive rationality* from *procedural rationality*. The former is the sort of rationality traditionally assumed by most economists in which people are able to achieve full optimization in their decisionmaking. The latter involves them selecting procedures or methods by which they can "do their best" in a world in which such full optimization is impossible, the heuristics by which they manage in a world of bounded rationality. In this regard it is not the case that Simon views people as being outright irrational or crazy. They have interests and they generally know what those are and they pursue them. However, they are unavoidably bounded in their ability to do so fully, so they must adopt various essentially ad hoc methods to achieve their satisficing goals.

Among these heuristics that Simon advocated for achieving procedural rationality were trial and error, imitation, following authority, unmotivated search, and following hunches. Pingle and Day (1996) used experiments to study the relative effectiveness of each of these, none of which clearly can achieve fully optimal outcomes. Their conclusion was that each of these can be useful for improving decisionmaking, however, none of them is clearly superior to the others use. It is advisable for agents to several of these and to move from one to another under different circumstances, although as noted above it may be hard to know when to do that and precisely how.[4]

2.3 Imitation and the Instability of Markets

While this list of procedures that can support a boundedly rational pursuit of procedural rationality is reasonable, a point not clearly made is that excessive focus on one of these rather than others can lead to problems. Clearly following authority can lead to problems when the authority is flawed, as many unfortunate examples in history have shown. Any of these can lead to problems if too intensively followed, but one that has particularly played an unfortunate role in markets is imitation, even though it is a widely used method by many people with a long history of being evolutionarily successful. The problem is particularly acute in asset markets, where imitation can lead to speculative bubbles that destabilize markets and can lead to much broader problems in the economy, as the crisis of 2008 manifestly shows.

A long literature (MacKay 1852; Baumol 1957; Zeeman 1974; Rosser Jr. 1997) has recognized that while agents focusing on long term fundamental values of assets tend to stabilize markets by selling them when their prices exceed these fundamentals and buying when they are below those, agents who chase trends can destabilize markets by buying when prices are rising, thus causing them to rise more, and vice versa. When a rising price trend appears, trend chasers will do better in returns than fundamentalists and imitation of those doing well will lead agents who might have followed stabilizing fundamentalist strategies to follow destabilizing trend chasing

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[4] More detailed studies of this issue can be found in Allen et al. (2011).

strategies, which will tend to push the price further up. And when a bubble finally peaks out and starts to fall, trend chasers can then push the price down more rapidly as they follow each other in a selling panic.

That such a tendency to engage in trend chasing speculation is deeply rooted in the human psyche was initially established experimentally by Smith et al. (1988), with many subsequent studies supporting this observation.[5] Even in situations with a finite time horizon and a clearly identified payment that establishes the fundamental value of the asset being traded, in experimental markets it has been repeatedly shown that bubbles will appear even in these simplified and clearcut cases. People have a strong tendency to speculate and to follow each other into such destabilizing speculation through imitation. Procedures that can support procedural rationality in a world of bounded rationality can lead to bad outcomes if pursued too vigorously.

We note that such patterns regularly take three different patterns. One is for price to rise to a peak and then to fall sharply after hitting the peak. Another is for price to rise to a peak and then decline in a more gradual way in a reasonably symmetric manner. Finally, we see bubbles rising to a peak, then declining gradually for awhile, finally collapsing in a panic-driven crash. Kindleberger's classic *Manias, Panics, and Crashes* (2001) shows in its Appendix B that of 47 historical speculative bubbles, each of the first two have five examples, while the remainder, the vast majority, follow the final pattern, which requires heterogeneous agents who are not fully rational for it to occur (Rosser Jr. 1997). This shows that complexity is deeply involved in most speculative bubbles.

Figures 2.1, 2.2, and 2.3 show the time path for prices of three bubbles before, during, and immediately after the 2008 crisis. They show the three patterns described above, taken from Rosser Jr. et al. (2012). The first is for oil, which peaked at $147 per barrel in July 2008, the highest nominal price ever observed, and then crashed hard to barely over $30 per barrel in the following November. It seems that commodities are more likely to follow this pattern than other assets (Ahmed et al. 2014).

The second pattern was followed by the housing bubble, which peaked in mid-2006 according to this figure, which shows two different indexes, the Case-Shiller 10-city one and their 20-city one as well. Looking closely one can see a bit of roughness around the peak making it look almost like the third pattern, whereas in fact if one looks at housing markets in individual cities, they look as posited by this pattern, with this roughness at the national level reflecting that different cities peaked at different times, with a final round of them doing so as late as January 2007 before they all declined.

This sort of pattern historically is often seen with real estate market bubbles. The more gradual decline than in the other patterns, nearly symmetric with the increase, reflects certain behavioral phenomena. People identify very personally and intensely with their homes and as a result tend not to easily accept that their home has declined

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[5] This result contrasts with earlier work by Vernon Smith (1962) showing how with double auction markets free markets converge rapidly to equilibria.

Fig. 2.1 Oil Prices, 2000–2011

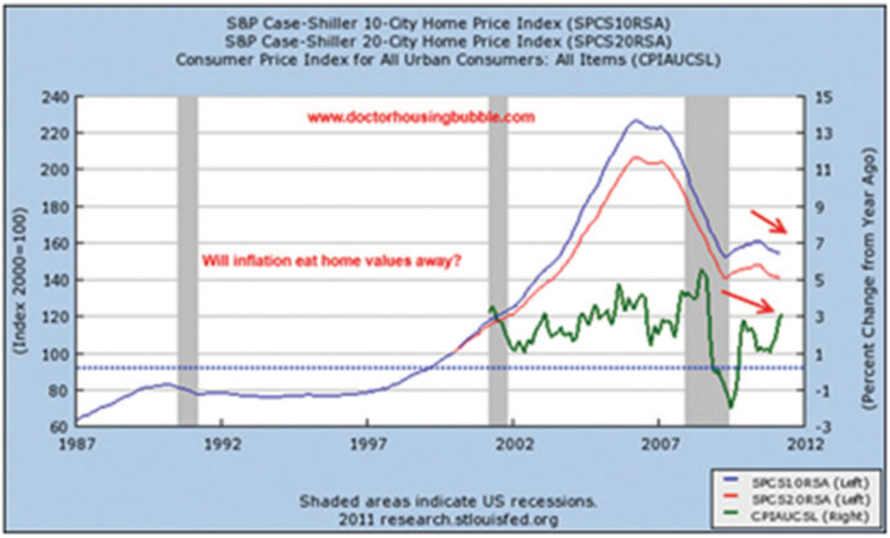


Fig. 2.2 Housing Prices in US, Case-Shiller Index, 1987–2013

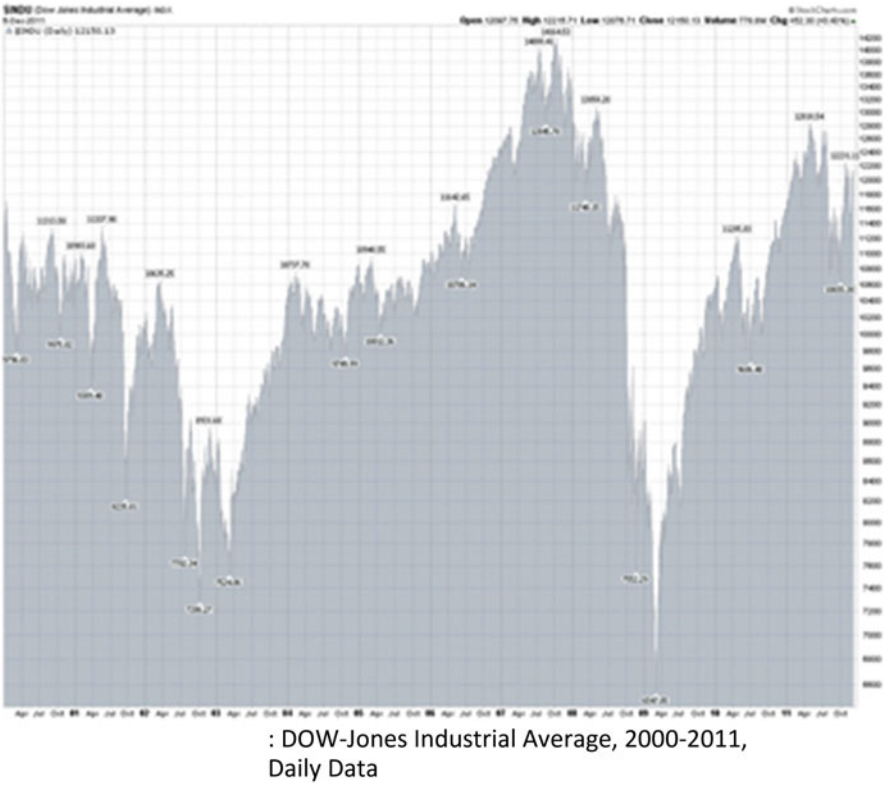
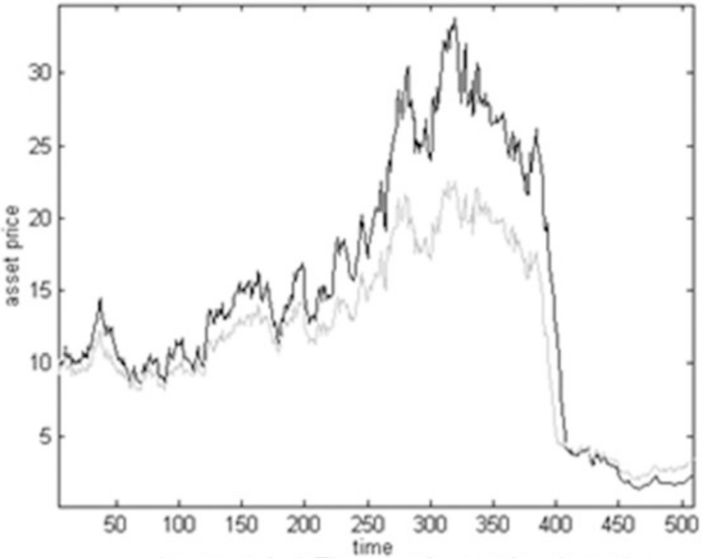


Fig. 2.3 US Stock Market Price Pattern, 2000–2011

in value whey they try to sell it during a downturn. As a result they have a tendency to offer prices that are too high and then refuse to lower their prices readily when they fail to sell. The upshot is a more dramatic decline in volume of sales on the downswing compared to the other patterns as people hang on and refuse to lower prices.

The third case shows the US stock market as exhibited by the Dow-Jones average, which peaked in October 2007, only then to crash in September 2008. Such patterns seem to be more common in markets for financial assets. Such patterns show heterogeneity of agents with different patterns of imitation, a smarter (or luckier) group that gets out earlier at the peak, followed by a less smart (or less lucky) group that hangs on hoping the price will return to rising, only to panic later en masse for whatever reason.

Finally, Figure 2.4 shows how this pattern with its *period of financial distress* (Minsky 1972) can be modeled in an agent-based model that has agents shifting from one strategy to another based on their relative successes, although not instantly (Gallegati et al. 2011). This model is based on ideas from Brock and Hommes (1997, 1998) that underlie the so-called Santa Fe stock market model (Arthur et al. 1997b).



Increase in J. The two time series share the same random numbers and same parameters but J. In the grey time series J = 0.5; in the black time series J = 3.

Fig. 2.4 Simulated Financial Distress Pattern

What triggers the delayed crash is agents running into financial constraints such as happens when individuals must meet margin calls in stock markets. The higher curve shows the pattern when agents imitate each other more strongly, as in a statistical mechanics model when there is a stronger interaction between particles.

2.4 Hierarchical Complexity and the Question of Emergence

While we can see Herbert Simon's discovery of bounded rationality as an indirect claim to being a "father of complexity," his most direct claim, recognized by Seth Lloyd in his famous list, is his 1962 paper to the American Philosophical Society on "The Architecture of Complexity." In this transdisciplinary essay he deals with everything from organizational hierarchies through evolutionary ones to those involving "chemico-physical systems." He is much concerned with the problem of the decomposability of higher-order systems into lower level ones, noting that productions ones, such as for watchmaking, as well as organizational ones, function better when such decomposability is present, which depends on the stability and functionality of the lower level systems.[6]

However, he recognizes that many such systems involve *near decomposability*, perhaps a hierarchical complexity equivalent of bounded rationality. In most of them there are interactions between the subsystems, with the broader evolution of the system depending on aggregated phenomena. Simon provides the example of a building with many rooms. Temperature in one room can change that in another, even though their temperatures may fail to converge. But the overall temperatures that are involved in these interactions are determined by the aggregate temperature of the entire building.

Simon also deals with what many consider to be the most fundamental issue involving complexity, namely that of emergence. His most serious discussion of the emergence of higher levels of hierarchical structure out of lower levels involves biological evolution, where these issues have long been most intensively discussed. He argues that how these higher levels emerged has not reflected teleological processes but strictly random processes. He also argues that even in closed systems, there need be no change in entropy in the aggregate when subsystems emerge within that system. But he also recognizes that organisms are energetically open systems, so that "there is no way to deduce the direction, much less the rate, of evolution from classical thermodynamic considerations" (Simon 1962, p. 8). However, it is the development of stable intermediate forms that is the key for the emergence of yet higher forms.

Simon does not cite this older literature, but this issue was central to the British "emergentist" literature that came out of the nineteenth century to become the dominant discourse in the 1920s regarding the broader story of biological evolution, all embedded within a broader vision fitting this within the emergence of physical and chemical systems from particles through molecules to such higher levels above biological evolution in terms of human consciousness, social systems, and yet higher systems (Lewes 1875; Morgan 1923) Simon dealt with this multiplicity of processes without drawing their interconnection as tightly as did these earlier figures. In the 1930s with the *neo-Darwinian synthesis* (Fisher 1930; Wright 1931; Haldane 1932), the emphasis returned to a near-continuous Darwinian process of gradual changes arising from the level of probabilistic changes arising from mutations at the gene level, with the gene the ultimate focus of natural selection (Dawkins 1976; Rosser Jr. 2011a, b).

While Simon avoided dealing with this issue of emergence in biological evolution in 1962, when the reductionist neo-Darwinian synthesis was at the highest level of its influence, soon the emergence view would itself re-emerge, based on multi-level evolutionary process (Crow 1955; Hamilton 1964; Price 1970). This would further develop with the study of nonlinear dynamics and complexity in such systems, with

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[6] See Rosser Jr. et al. (1994) for discussion of different forms of hierarchical relationships and emergence. Rosser Jr. (2010b) provides discussion of relations between *multidisciplinary, interdisciplinary, and transdisciplinary*.

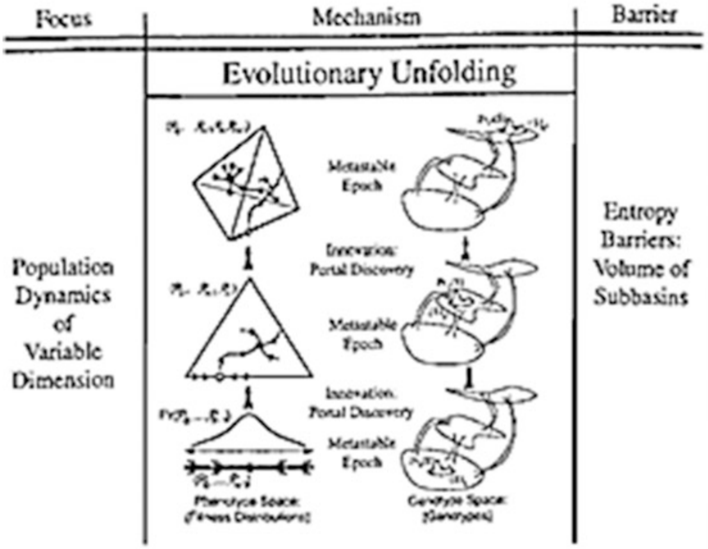

Fig. 2.5 Evolutionary Emergence

such figures as Stuart Kaufffmann (1993) and James Crutchfield (1994, 2003), who draw on computational models for their depictions of *self-organization* in biological evolutionary systems.

Figure 2.5 from Crutchfield (2003, p. 116) depicts how an initial genetic level mutation can lead to emergent effects at higher levels. On the right side are genotypes moving upwards from one basin of attraction to another, while on the left side phenotypes are also doing so in a parallel pattern. He introduces the concept of *mesoscales* for such processes, which clearly follow Simon's admonition about the necessity of stable intermediate systems emerging to support the emergence of yet higher order ones.

This view remains questioned by many evolutionists (Gould 2002). While the tradition going through catastrophe theory from D'Arcy Thompson (1917) has long argued for form arising from deep structures in organic evolution, critics have argued that such self-organizing processes are ultimately teleological ones that replicate old pre-evolutionary theological perspectives such as Paley's (1802) in which all things are in their place as they should be due to divine will. Others have criticized that such processes lack invariance principles (McCauley 2005). Others argue a more computational base for such processes (Moore 1990). There is no easy resolution of this debate, and even those advocating the importance of emergent self-organization recognize the role of natural selection. Thus, Kaufffmann (1993, p. 644) has stated, "Evolution is not just 'chance caught on a wing.' It is not just a tinkering of the ad hoc, of bricolage, of contraption. It is emergent order honored and honed by selection."

While the mechanisms are not the same, the problems of emergent self-organization apply as well to socio-economic systems. Simon's focus tended to be on organizations and their hierarchies. While he may well have sided with the more traditional neo-Darwinian synthesizers when it came to emergence of higher order structures in biological evolution, the role of human consciousness within human socio-economic systems means that the rules are different there, and the formation of higher order structures can become a matter of conscious will and planning, not mere randomness.

2.5 Bounded Rationality and Learning to Believe in Chaos

One of the greater ironies regarding bounded rationality is that it was colleagues of Herbert Simon's at Carnegie-Mellon, particularly John Muth (1961), who developed the idea of rational expectations while studying implications of bounded rationality. Muth in particular saw the assumption of rational expectations as a solution to the problems raised by bounded rationality. However, Herbert Simon would never have anything to do with this development, seeing it as a repudiation of bounded rationality. The idea that people not only know what is the true model of the economy, but that their subjective view of the probability distribution of exogenous noise in the system corresponded with the objective probability distribution of such noise, which was also conveniently Gaussian, simply was not acceptable in his view. Quite aside from the inability of boundedly rational agents to discern the "true model of the economy," he would never accept the idea that noise would be Gaussian. Indeed, he was a deep student of power law distributions that exhibit kurtosis or "fat tails" (Simon 1955b), hence he did not join his colleagues in their elation at the development of this idea.

That said, under certain circumstances it can come to pass that simple heuristic rule of thumb behaviors may do well in a world of complex nonlinear dynamics at helping boundedly rational agents mimic underlying dynamics that may even be chaotic. This can arise if agents are able to achieve *consistent expectations* or CEE (Hommes and Sorger 1998), an idea derived from work by Grandmont (1998) that had been done earlier, even though it was only published in the same year as theirs. An example of this was studied by Hommes and Rosser Jr. (2001) for fishery dynamics when these might exhibit chaotic patterns. Such patterns can arise due to the tendency of fisheries to exhibit backward-bending supply curves due to the carrying capacity limits of most fisheries. When prices go beyond a certain level that is consistent with *maximum sustained yield* the amount of fish will decline and fewer will get caught.

From Rosser Jr. (2001b), X is the biomass of fish in the fishery, with $F(X)$ being the growth rate of X, which in turn equals steady state harvest yields from the fishery, h, which in turn equals Q in the supply-demand diagram in the upper right portion of the figure. The bionomic portion is in the lower right part of the diagram and reflects a Schaeffer (1957) yield function, with r being the unconstrained natural growth rate of the fish population and K the carrying capacity of the fishery:

$$Q = h = F(X) = rX(1 - X/K). \tag{2.1}$$

This logistic is well known to be able to exhibit chaotic dynamics when in a discrete form from the work of May (1976). Following Gordon (1954) with $E =$ catch effort measured by time boats are out, $q =$ catchability per vessel per day, $C =$ cost, with constant marginal cost $= c$, $p =$ price of fish, and δ the time discount rate, then cost is given by

$$C = c/qX, \tag{2.2}$$

and the basic harvest function can be given by

$$h(X) = qEX. \tag{2.3}$$

Drawing on Clark (1990), Hommes and Rosser Jr. (2001) derived a full supply curve that varies with δ. This slopes upwards for $\delta = 0$, asymptotically approaching the output level associated with maximum sustained yield, but bends backwards for $\delta > 0.02$, reaching a maximum backward bend at $\delta = \infty$, at which point the supply curve is identical to the open access equilibrium due to Gordon (1954) given by

$$S(p) = rc/pq(1 - c/pqK), \tag{2.4}$$

with linear demand curve given by

$$D(p) = A - Bp. \tag{2.5}$$

Hommes and Rosser Jr. (2001) describe the cobweb dynamics of such a fishery under adaptive expectations by means of a discrete function

$$P_t = [A - S_\delta(p_{t-1})]/B. \tag{2.6}$$

Hommes and Rosser Jr. (2001) show that this can be chaotic for given values of δ as S varies with it. This will occur when S is backward-bending in those portions, which can also lead to catastrophic outcomes as demand shifts (Copes 1970).[7]

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[7] Rosser Jr. and Rosser (2006) consider problems of managing such catastrophic outcomes within an institutionalist framework.

The question of boundedly rational fishers arises if we allow them to base their expectations on a simple heuristic, p^e representing expected price, of a one-period autoregressive process given by

$$P^e(t) = \alpha + \beta(p_{t-1} - \alpha). \tag{2.7}$$

This AR(1) process can change according to sample autocorrelation learning in which the agents over time adjust the two control parameters, α and β, based on the performance of the fishers. Based on the CEE and assuming that the underlying chaotic dynamic for the optimizing fishery is given by an asymmetric tent map, Hommes and Rosser Jr. (2001) show that these parameters can converge on values such that this simple AR(1) heuristic will reproduce the underlying chaotic dynamic, which will be a CEE.

This is shown in Fig. 9 of Hommes and Rosser Jr. (2001), where the fishers start out catching a given level of X assuming a constant p, but as β in particular initially changes, a two-period motion appears, which then goes chaotic after later adjustment by both of the parameters occurs. This process has been called *learning to believe in chaos* We note that this dynamic remains bounded as are all chaotic dynamics, thus avoiding catastrophic collapse, a case of chaos preventing catastrophe. While this replicates to some extent standard figures showing period-doubling bifurcations to chaos, this is not one of those that involve a growth parameter varying. Rather this is a process of converging on a behavioral pattern based on autoregressive parameters adjusting in real time, not the same thing, even if it resembles it.

2.6 Behavioral Economics and Keynesian Uncertainty

Herbert Simon largely avoided directly addressing macroeconomic implications of his ideas, beyond expressing his disapproval of the rational expectations hypothesis that many claimed derived from his work, with this even being asserted as something so fundamental that it was axiomatic and could not be challenged for deep theoretical and philosophical reasons, despite its obvious and well known failure to follow empirical reality, a point that Simon was fully aware of. Given that his concept of bounded rationality violates full rational expectations, and also the deep connection with nonlinear dynamic complexity that has been presented earlier in this chapter, although not as fully as it might have been, the question arises, pushing beyond just bounded rationality to behavioral economics more broadly, what is the relationship between these ideas and the deep Keynesian (and Post Keynesian)[8] idea of fundamental uncertainty?

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[8] In contrast, post-Walrasian economics (Colander, 2006) critiques and tries to move beyond the Walrasian framework, while Post Keynesian (also called "post-Keynesian") economics tends to

The conventional view is that in 1921 Frank Knight and John Maynard Keynes both published books that established the distinction between *risk* and *uncertainty*, with Knight having clearly coined this distinction, but with Keynes's work exploring the distinction more deeply as he adopted the same terminology later (Keynes 1936; Rosser Jr. 2001a). "Risk" is quantifiable in terms of being able to identify a probability distribution that is relevant to understanding a problem. "Uncertainty" means that there is no such identifiable probability distribution. In contrast to Knight, Keynes was more aware of the possibility of various intermediate possibilities arising from inability to estimate the quantitative measure for either data availability or other reasons, as well as recognizing the difficulty of separating a variety of probability distributions possibly appropriate. This latter is a matter that has become more heavily discussed particularly since the 2008 financial crisis as the role of kurtosis or "fat tails" in financial returns has become more publicized.

The range of possibilities has been heightened by such observers as Nassim Taleb (2010) who distinguishes *grey swans* from *black swans.* The former involve probability distributions that show fat tails and are known, which can potentially explain extreme outcomes in financial markets and other situations. The latter involve true Keynesian/Knightian uncertainty, where it is impossible to assign a probability distribution, and where the events described "come out of nowhere" without any possibility of forecasting or expecting them. In this regard, Taleb argued that the 2008 crisis was a mere grey swan, an extreme outcome, that nevertheless was obviously coming and to be expected by any reasonable observer, in contrast with the October 19, 1987 crash of the stock market, 22% for the Dow-Jones average, to this day the largest one day decline ever, which was predicted by nobody and had no obvious cause, which "came out of nowhere," and which was a true black swan, an example of true and fundamental uncertainty.[9]

Rosser Jr. (1998, 2006) has argued that complexity provides a fundamental foundation for the reality of fundamental uncertainty. Paul Davidson (1996) has argued that this is not the case, that not only complexity, but such notions as Simonian bounded rationality are not proper or fundamental foundations of fundamental uncertainty. He distinguishes *ontological* uncertainty from *epistemological* uncertainty, arguing that true Keynesian uncertainty is the former based on the reality of non-ergodicity in most dynamic relations in the real world (Davidson 1982-83). In contrast he sees bounded rationality and the various variabilities arising

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admire the ideas of Keynes to varying degrees among the variety of schools of Post Keynesian thought, with Harcourt and Kreisler (2013a, b) providing an overview of these schools.

[9] There is no definitive separating these cases as even Gaussian distributions allow for extreme outcomes, if less frequently than those exhibiting kurtotic fat tails. In Tom Stoppard's (1967) *Rosencrantz and Guildentstern are Dead* the opening sequence has the ultimately doomed characters arguing about flipping coins when one of them keeps flipping heads "against all odds" 92 times in a row, an ouitcome allowed by probability distributions where the probability of a head is one half for each fair coin toss. Even Keynes accepted such a result and noted that insurance companies make profits from betting on identifiable and measurable probability distributions, even as he argued for fundamental uncertainty for many situations.

from nonlinear complex dynamics as being merely epistemological. If only people had really accurate and precise knowledge and forecasting systems, they could overcome these difficulties. Simon's emphasis on knowledge limitations and computational limitations by individuals come under special scrutiny and criticism in this regard. The foundation of bounded rationality (and complexity) is not fundamental uncertainty, but mere inability to compute and know. If only we had supercomputers with superknowledge, all would be well.

There is no ultimate resolution of this debate, although it must be noted that a major source of non-ergodicity within many systems is nonlinearity of the underlying dynamical relationships that leads to complexity. But as is well known in the econometric study of chaotic dynamics, it is profoundly difficult to distinguish deterministic chaotic dynamics from random noise (Dechert 1996). This debate faces this deep uncertainty of its own.

As it is, while behavioral economics may or may not be the foundation of true Keynesian/Knightian uncertainty, Talebian black swans, but it may provide a possible way to deal with policy in a world subject to such uncertainty from whatever source. Thus, while it remains absurdly ignored by many macroeconomists, George Akerlof's (2002) *behavioral macroeconomics* is almost certainly strongly affecting policymakers in practice, even if they do not speak openly of its influence. Real world central bankers and other macroeconomic policymakers are following heuristic behavioral patterns as recommended by the late Herbert A. Simon, even if few of them will admit to doing so.

2.7 Behavioral Economics and the Complexity of Institutional Evolution

The link between institutional economics and evolutionary economics dates to the work of Thorstein Veblen (1898). It is largely in recognition of this fact that the first organization in the United States dedicated to the study of institutional economics is called the Association for Evolutionary Economics,[10] with similar names being used in other nations for such study, including in Japan (Shiozawa et al. 2019). While it was not recognized at the time and remains little known, Veblen not only called for economics to be an *evolutionary science*, but introduced certain ideas that have since proven to be important in understanding the nature of complexity in economics, particularly that of *cumulative causation*, often,[11] thought by many to have been

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[10] In the U.S. this society has been closely associated with the so-called "old institutional economics," whereas it may be that an evolutionary approach taking into account complexity can unite the old and new approaches.

[11] It is an open debate whether or not Veblen viewed cumulative causation as necessarily implying economies of scale, although he was aware of the importance of economies of scale in industrial systems (Veblen, 1919). Setterfield (1997) recognizes Veblen's priority in introducing the concept,

introduced later by either Allyn Young (1928) or Gunnar Myrdal (1957), with the latter making the term widely known among economists. Among the various forms of complexity that are relevant to economics, cumulative causation is most obviously tied to *dynamic complexity*, which leads to increasing returns, multiple equilibria, and a variety of bifurcations in economic dynamical systems. However, it can be seen to be connected also to *computational complexity*, the main rival to dynamic complexity in economic analysis.

An important issue for the matter of how evolutionary theory relates to institutional economics in its early formulation involves Veblen's relations with John R. Commons and Joseph Schumpeter. Veblen developed ideas of Darwinian evolutionary economics in the early twentieth century in the United States, while Schumpeter is widely viewed as a strong supporter of an evolutionary approach to economic development, particularly regarding the evolution of technology, even as he criticized institutional economics and the application of biological ideas (Rosser Jr. and Rosser 2017). Also not widely known, Commons (1924) also supported an evolutionary view, although he had more of a teleological perspective on that than did either Veblen or Schumpeter, both of whom saw no necessary direction to technological evolution and change (Papageorgiou et al. 2013). Dealing with a complexity issue, Schumpeter strongly advocated a discontinuous, or *saltationalist* view of evolution (Schumpeter 1934; Rosser Jr. 1992), which Veblen agreed with regarding technological change. Regarding institutional evolution Veblen mostly saw it proceeding in a more continuous manner through cumulative causation, thus being somewhat closer to Commons on that matter, even as he argued that it was fundamentally unstable and would experience crises and breakdowns.

A central issue for institutional economics is the distinction between institutions and organizations (North 1990). This becomes central for the role of evolution in economics, in particular what is the meme that is the locus of evolutionary natural selection. In older literature the emphasis was more on organizations, such as with Commons (1934) who saw organizations competing with each other, a theme also picked up by Alchian (1950), even as Commons emphasized the deeper structures of institutions in legal systems. While organizations compete, increasingly evolutionary economists have focused on practices and routines as the more crucial memes, with this an especial theme among neo-Schumpeterian followers such as Nelson and Winter (1982).

An important element of evolutionary processes is the emergence of higher level structures out of lower level and simpler ones. This is more obvious in terms of organizations, but in institutional evolution the role of memes becomes crucial. This fits with the issue of multi-level evolution, long controversial in evolutionary theory (Heinrich 2004). Within human systems this becomes tied to cooperation, with Ostrom (1990) developing how such cooperation can arise through particular

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but argues that Young (1928) and Kaldor (1972) more clearly tied it to the phenomenon of increasing returns.

institutions. This process of emergence is linked to deep concepts of complexity, with Simon (1962) a crucial developer of this line of thought.

Understanding the complex dynamics of institutional evolution can bring about a possible reconciliation or even synthesis between the old and new institutional economics. Coase (1937) recognized that Commons originated the idea of the importance of transaction costs, the centerpiece of the new institutional economics (Williamson 1985). Mikami (2011) that has argued that the effort to minimize transactions cost can lead to complex evolutionary dynamics. This can involve Veblen's cumulative causation, recognizing how this can become linked to complex evolutionary emergence.

At the time when Thorstein Veblen was writing his most important works when the nineteenth century was turning into the twentieth, there was no clear or general awareness of what we now call *complexity*, even as many ideas we now associate with it had been floating around in various disciplines for many years, especially in mathematics and even somewhat in economics (Rosser Jr. 2009b). We have no reason to believe that Veblen was particularly aware of these strands, although evolution itself is now viewed as a complexity process par excellence (Hodgson and Knudsen 2006), which Veblen would strongly advocate.[12] In any case, central to Veblen's approach to economic evolution was his invocation of the idea of *cumulative causation*, which he was the first to introduce.[13] We must note that cumulative causation can lead to dynamic complexities through increasing returns, which Brian Arthur (1989, 1994) has argued is the central key to understanding complexity, and which Veblen recognized as present in industrial technology.

2.8 The Discontinuity Debate in Evolutionary Theory

It was Leibniz who initially coined the phrase *natura non facit saltum*, or, "nature does not take a leap." It would be picked up by Darwin himself who repeated it and applied it to his theory of natural selection, and Marshall would follow Darwin in applying to economics, repeating it in the Prefaces to all eight editions of his *Principles of Economics*. For Darwin (1859, pp. 166–167):

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[12] Veblen was not the first economist to advocate the usefulness for economics of evolutionary theory, with both Marx and Marshall doing so before he did, even as they did so from very different perspectives. The more complicating factor in all this is the fact that Darwin himself was crucially influenced by Malthus's work on population when he developed his theory of natural selection (Rosser Jr., 1992).

[13] That this is not widely known can be seen in that Business Dictionary identifies the originator of the term as Allyn Young (1928) [www.businessdictionary.com/definition/cumulative-causation.html] and Wikipedia identifies its originator (actually "Circular cumulative causation") as being Gunnar Myrdal (1957) [https://en.wikipedia.org/wiki/Circular_cumulative_causation]. Certainly Myrdal's use of the term received widespread attention.

"Natura non facit saltum...Why should not Nature take a leap from structure to structure? On the theory of natural selection we can clearly understand why she should not: for natural selection can only act by taking advantage of slight successive variations; she can never take a leap, but must advance by the shortest and slowest steps."

This was a strong statement for Darwin to make given that he did not understand the underpinnings of how the process of mutation through changes in genes worked, but indeed many evolutionary theorists since Darwin have been impressed by the idea that only minor changes in genes can occur at a time for species to be viable and survive and reproduce, thus setting up at least most evolutionary processes to be slow and gradual as asserted by Darwin. However, until the understanding of genetics was fully integrated into Darwinian theory with the neo-Darwinian synthesis in the 1930s, there was more of an opening for more noticeable discontinuous change in the Lamarckian perspective that allowed for the inheritance of acquired characteristics, and thus more rapid evolutionary change.

After the 1930s the more dramatic reassertion of the possibility for rapid change in the form of *punctuated equilibrium* would come with Eldredge and Gould (1972), whose arguments remain controversial among evolutionary biologists. However, the groundwork for their arguments was laid in the development of the neo-Darwinian synthesis itself during the 1930s, even if it was not clearly recognized at the time. A central part of the neo-Dawinian synthesis, especially as formulated by Fisher (1930), involved focusing on the gene, with natural selection operating at the level of the gene, which contrasted with theories that saw natural selection operating at higher levels on wholes. Changes at the level of a gene must be fairly small to be viable, but a method of studying this through fitness landscapes as introduced by Sewall Wright (1932) opened the door for a broader perspective, one that can be carried over to the study of institutional evolution (Mueller 2015).

A piece of groundwork always there regarding Wright's fitness landscape framework that opened the door to such saltationalist discontinuities or punctuations was that Wright from the beginning allowed for multiple local optima or equilibria within those landscapes. While he himself did not see dramatic discontinuities happening at the genetic level, he recognized that rapid environmental changes could shift the landscapes so that a former peak could fairly quickly become a valley and the nearest peak reachable by a gradient might be some distance away, which would imply some rapid evolution, if not necessarily discontinuous in genotype and phenotype.[14]

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[14] Clearly there is no definitive boundary in observing what is essentially discrete data between what is continuous and discontinuous. In biological evolution one observes different individuals across generations, and, with the exception of identical twins or clones, each individual's genotype is discretely distinct from every other's. Likewise with phenotypes, one might depict the possible variations of a certain physical characteristic on a continuous scale, but individuals will still have discrete differences from other individuals on such characteristics, even if these are very small. Thus the distinction becomes arbitrary. At the lowest level we see a discontinuous granularity, but a a higher level defenders of continuity see only gradual changes, especially in population averages, with it completely open to debate how rapid such changes must be before one can call then

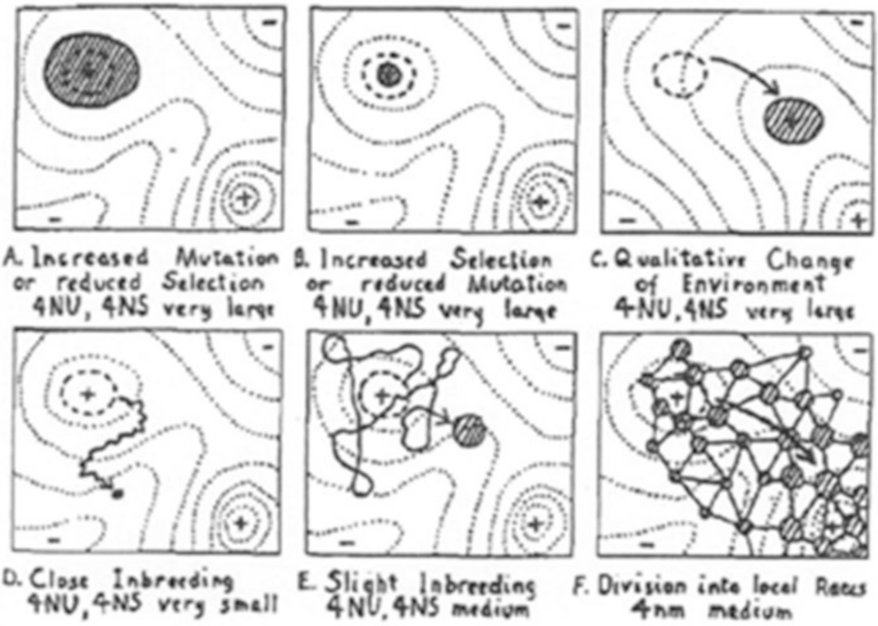

Fig. 2.6 Sewall Wright's fitness landscapes

Figure 2.6 shows Wright's original depiction of fitness landscapes and certain cases that could happen (Wright 1932, reproduced in Wright 1988, p. 110), with box C showing the case just described, a changing of the landscape due to some environmental change, which might happen quite suddenly.

Regarding the application of these ideas to economic evolution and more specifically institutional evolution, it is generally accepted that while Marshall may have agreed with Leibniz and Darwin that *natura non facit saltum*, Veblen tended to accept the idea that institutional evolution could be discontinuous, or at least that institutional equilibria were not stable and could change suddenly. Thus he declared (Veblen 1919, p. 242–243):

> "Not only is the individual's conduct hedged about and directed by his habitual relations to his fellows in the group, but these relations, being of an institutional character, vary as the institutional scene varies. The wants and desires, the end and the aim, the ways and the means, the amplitude and drift of the individual's conduct are functions of an institutional variable that is of a highly complex and unstable character."

Curiously while Schumpeter strongly supported the idea of discontinuous technological change and used the language of evolution in the context of economic development, he rejected the use of biological analogies in such discussions,

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discontinuous (see Rosser Jr., 2000a, Chap. 1, for further discussion of distinguishing continuous from discontinuous forms).

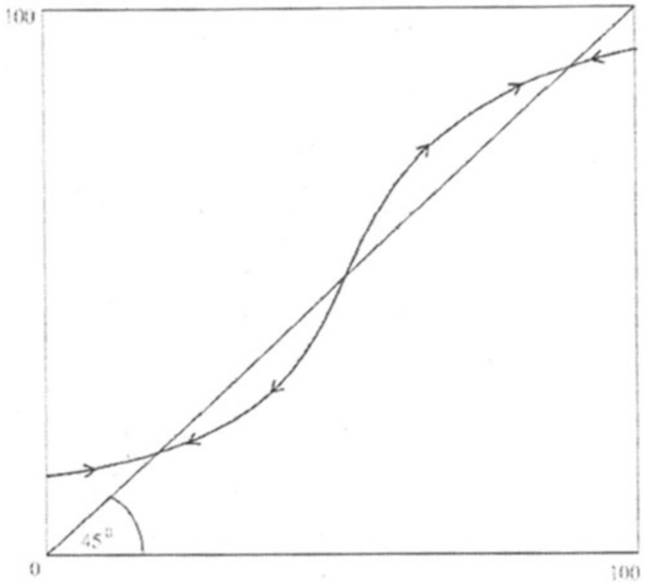

Fig. 2.7 Multiple social equilibria

declaring that (Schumpeter 1954, p. 789), “no appeal to biology would be of the slightest use.” He dismissed selective mechanisms whether of a Darwinian or Lamarckian sort, using the word “evolution” in a simply developmental way (Hodgson 1993a, b).

While Wright did not spell it out, a key to the existence of multiple local equilibria in his fitness landscapes is the presence of some sort of increasing returns. This brings in Arthur’s (1994) emphasis on increasing returns and its link to the existence of multiple equilibria and dynamic complexity,[15] which carries over to institutional evolution. Minniti (1995) used a variation of the Arthur et al. (1987) urn model to show how low and high crime equilibria can arise in a society, with social interactions providing positive feedbacks the key to such an outcome, with potential discontinuities arising as the amount of crime can shift very suddenly from one state to another. This is shown in Fig. 2.7 where the horizontal axis is the percent of the population who are criminals while the vertical axis shows the probability that a new entrant to society will be a criminal. Rosser Jr. et al. (2003b) applied this model informal economies in transition economies, with there also being multiple equilibria as seen by large differences in this variable among the transition economies of Eastern Europe, with the degree of inequality playing an important role as discussed in the next chapter.

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[15] The original formulation of Arthur’s model was from Arthur et al. (1987) and their study of Polya urns.

2.9 Institutions, Organizations, and the Locus of Economic Evolution

If economies are evolutionary systems, then the question of what is the locus of that evolution is important. Hodgson and Knudsen (2006) argue that there are three crucial characteristics involved in truly Darwinian evolution: variability, natural selection, and inheritance. For something to qualify as a locus of evolution it must exhibit all three of these. In biological evolution the gene certainly fulfills all of these: mutation provides random variability, natural selection determines whether an organism containing a gene will survive or not, and genes pass from one organism to another through reproduction if the organism is able to survive and attract mates to effectuate this. Critics of evolutionary economics argue that there is no definitive unit or element in economies that fulfill all three of these, even if many fulfill some of them.

Given the long advocacy by institutionalist followers of Veblen for making economics an evolutionary science, these issues have been central to debates within this area. A focus on organizations has long attracted attention, with this arguably more important to Commons than to Veblen. For Commons, directed or artificial selection was more important than strictly random natural selection, and he noted that Darwin himself spent much time discussing both random natural selection as well as artificial breeding (Commons 1934, p. 657; Vanberg 1997).[16] Commons saw organizations as being subject to direction and thus appropriate objects for this sort of directed evolution, which had a goal of general human improvement. In his argument for evolution as the fundamental force in microeconomics, Armen Alchian (1950) emphasized the competition of firms, with the survival of the fittest involving which firms can come closest to maximizing profits, even if they do not know precisely how they are doing so, with firms clearly the locus of evolution.

A criticism of the idea of firms, or more generally organizations, serving as the key locus of evolution in economics is that while they are subject to random variability as they experience shocks from the system, and natural selection clearly operates in their competition with each other, with unprofitable firms failing to survive, the missing piece is that of inheritance. Firms and organizations do not essentially reproduce themselves. All they do is survive, although they may change while doing so. These changes may reflect these evolutionary forces of natural selection, but the inheritance element of their doing so must be operating at some lower level than that of the firm or organization itself.

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[16] Curiously Sewall Wright also focused on animal breeding due to his working for the US Department of Agriculture in the 1920s, where his thinking about this led him to certain of his ideas such as random drift, also known as "the Sewall Wright Effect," sometimes seen as a violation of strict natural selection in how new species might form, although the separation of genetically distinct sub-groups of a population may happen either randomly in nature or through the conscious control and direction by humans as in animal breeding.

The leading alternative for serving as the evolutionary meme[17] is habits or practices within an organization. While they were not driven to this argument by trying to fit new institutional economics into an evolutionary framework per se, this is how North (1990) and Williamson (2000) define institutions. They are habits or practices, not organizations. This is also what Nelson and Winter (1982) came to in their search for the key to evolutionary economics, although they labeled these memes to be "routines." But prior to any of these and prior to Commons and his emphasis on organizations, Veblen identified habits, including habits of thought, as the central locus of evolution in economic institutions, declaring (Veblen 1899, pp. 190–191):

> "The situation of today shapes the institutions of tomorrow through a selective, coercive process, by acting upon men's habitual view of things, and so altering or fortifying a point of view or a mental attitude handed down from the past."

Given that as he put it the individual's conduct is "hedged about by his habitual relations with his fellows in the group," with these relations of an "institutional character," it is habits and habitual relations that are at the foundation of the evolution of institutions, even if he sees these institutions as being higher order social structures. It is the habits that are at the foundations, and habits can change, leading to new habits that may be inherited by the individuals and organizations using them.[18]

2.10 Emergence and Multi-Level Evolution

Among the ideas most strongly associated with complexity is that of *emergence*, that a higher order entity arises out of a lower level one that is not simply the sum of the parts of the lower level one, that the emergent entity is something qualitatively different. While the idea of a whole being greater than the sum of its parts has been around for a long time, a scientific formalization of it is probably due to John Stuart Mill (1843) in his discussions of logic in which he characterized situations where something qualitatively different from its parts appears as representing *heteropathic laws*. His original examples involved chemistry such has how salt appears when one combines sodium with chlorine, with salt not being at all like either of them separately. Lewes (1875) applied the term *emergence* to such phenomena. This led to the "British Emergentist" school of thought that especially in the 1920s (Morgan 1923) would apply this concept to evolution, in particular to such problems as how multi-cellular organisms arose out of uni-cellular ones. It would be applied to how larger social groups would organize themselves to act together out of previously

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[17] The term "meme" as the locus of evolution is due to Dawkins (1976), who also first proposed the idea of "universal Darwinism."

[18] How evolution of habits and norms determines tax behavior in societies is studied by Torgler (2016).

smaller separate groups, an idea clearly important in the evolution of institutions (McLaughlin 1992).

In biological evolutionary theory this view fell out of favor in the 1930s with the rise of the neo-Darwinian synthesis, which put the focus on the gene as the locus of evolution, the meme, as Dawkins (1976) labeled it. The idea that natural selection occurred at levels above the gene, at the level of "wholes" or groups, was specifically rejected (Williams 1966). The obvious counter to this in biological evolution involves the social insects (Wilson 2012), in which individuals are subordinated to the good of the colony, with the colony becoming the vehicle of evolution. Most attribute the mathematical understanding of how this can arise to the work of Price (1970) and Hamilton (1964, 1972). However, in fact, the original formalization of this understanding in terms of within-group versus between group selection was due to Crow (1955).

Let B_w be the within-group genic regression on the fitness value of the trait as defined by Wright (1951); B_b be the between-group genic regression to the fitness value; V_w be the variance among individuals within a group, and V_b be the variance among means across groups. For an *altruistic gene* one would expect B_w to be negative (that the behavior within the group damages the individual), while B_b would be positive (the behavior of the individual helps the group). From this a sufficient condition for the altruistic gene to increase in frequency is given by

$$B_b/(-B_w) > V_w/V_b. \tag{2.8}$$

Within biology there it has been widely argued that this condition rarely holds. However, it has also been recognized that it appears to hold for the social insects, and as Wilson (2012) argues, this implies that even though only a minority of species show this characteristic, they end up constituting a huge portion of the animal biomass on the earth (especially if one includes human beings in that calculation).

Indeed, this formulation can be carried over to humans to resolve the problem of cooperation versus cheating within a Prisoner's Dilemma game theoretic context (Heinrich 2004). The specific problem for humans becomes one of recognizing who is a cooperator and who is not within social groups, with successfully doing so being the condition for cooperation and a higher level coordination to come about. Considering in detail how such cooperation can arise in numerous contexts for dealing with common property resources was the central focus of the work of Ostrom (1990). This can more generally be viewed as a condition for the emergence of higher level institutions out of lower level ones.[19]

Somewhat parallel to this is a formulation of emergence in biological evolution due to Eigen and Schuster (1979) known as the *hypercycle*, which involves information preservation and transmission, tying this more to computational forms of

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[19] Sethi and Somanathan (1996) show that in such games there are multiple Nash equilibria, with some supportive and some destructive of the cooperative equilibria that are consistent with sustainable development. Rosser Jr. and Rosser (2006) extend this argument.

complexity. “the simplest system that can allow the evolution of reproducible links” (Eigen and Schuster 1979, p. 87). They define a *threshold of information content,* which if exceeded for a system will lead to a degeneration of information due to an *error catastrophe*. Above an error catastrophe there is a “disintegration of information due to a steady accumulation of errors” (Eigen and Schuster 1979, p. 25).

Let V_{m} be the number of symbols, $\sigma_{\mathrm{m}} > 1$ be the degree of selective advantage superiority of the “master copy,” and q_{m} be the quality of symbol copying. The threshold is then given by

$$V_{\mathrm{m}} < \ln \sigma_{\mathrm{m}}/(1 - q_{\mathrm{m}}). \tag{2.9}$$

Such hypercycle formation has been simulated by Mosekilde et al. (1983), and the concept has been applied to the evolution of market structures based on differential rates of learning among firms by Silverberg et al. (1988). It has also been linked with the concept of *autopoesis*, defined as the stable reproduction of a space-time structure (Varela et al. 1974).

This can be seen as linked to *self-organization* as initially formulated by Turing (1952) in the form of *morphogenesis*. When such morphogenesis involves emergence at a higher level this become *hypercyclic morphogenesis* (Rosser Jr. 1991, Chap. 6), or the *anagenetic moment* by Rosser Jr. et al. (1994). Radzicki (1990) applied such arguments to the question of the formation of institutions out of underlying chaotic dynamics.[20] Within evolution the emergence of higher hierarchical levels was also the central focus of Simon (1962).

This raises parallels within evolutionary game theoretic models of the issue of *multi-level evolution* (Heinrich 2004), with the Price-Hamilton equations providing sufficient conditions for this to occur, although the original version was due to Crow (1955). For its population, B_{w} and B_{b} are within- and between-group genetic regressions of fitness on the value of the trait, V_{w} and V_{b} are the within- and between-group genetic variances, with W the mean population fitness, then

$$\Delta C = (B_{\mathrm{w}}V_{\mathrm{w}} + B_{\mathrm{b}}V_{\mathrm{b}})/W. \tag{2.10}$$

This allows for a statement of Hamilton’s (1972) condition for an altruistic trait to increase (the equivalent of cooperation at a higher level) as

$$B_{\mathrm{w}}/(B_{\mathrm{b}} - B_{\mathrm{w}}) < r, \tag{2.11}$$

where r is the Sewall Wright coefficient of relationship (Crow and Aoki 1984). The left-hand side can be interpreted as a cost-of-fitness to benefit-minus-fitness ratio.

Another strand of emergent evolutionary processes is associated with the neo-Schumpeterian view strongly associated with Nelson and Winter (1982) and

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[20] Some of the early models of hypercycle formation required the absence of parasites. Howver, with appropriate mixing they may be stable against parasites (Boerlijst and Hogeweg, 1991).

their study of what are the key memes in evolutionary economics. They are known for their advocacy of the idea that routines are the key meme that is the locus of such evolutionary developments. Nelson and Winter themselves were less focused on this matter of emergent higher orders that become the locus of evolution, but some of their followers have pursued such ideas. In particular has been the development of the idea of *mesoeconomics* by Dopfer et al. (2004), originally due to Ng (1986). This is a level of economics that is intermediate in level between the microeconomics of the firm where the Nelson and Winter processes presumably mostly operate and the fully aggregated level of macroeconomics. The mesoeconomic level is more at the industry or sector level where a meme may have diffused across firms within a sector or even a set of related sectors. Such developments can lead to this being the most important part of the economy from the standpoint of growth and evolutionary development.

In terms of institutional evolution operating at higher levels of emergent structures, a possibly surprising supporter of this view is Austrian economist, Friedrich Hayek. This would appear to be at least partly associated with his open embrace of complexity (Hayek 1967) and especially in connection with this the concept of emergence, harking openly back to the British emergentists of the 1920s. His opening to this strand of thought came from his early work in psychology that culminated in his *The Sensory Order* (Hayek 1952). In this work he specifically saw human consciousness as an emergent property arising from the nervous system and the brain (Lewis 2012). Crucial in his formulating this was the influence of systems theory as developed by Ludwig von Bertalanffy (1950), who in turn was influenced by the *cybernetics* of Norbert Wiener (1948), thought by many to be another early form of dynamic complexity. Lying more deeply behind cybernetics was the development of the "universal system of organizations" or *tektology* of A.A. Bogdanov (1925-29), arguably a form of evolutionary institutional economics stressing emergence.[21]

Indeed, Hayek (1988) in his final work, *The Fatal Conceit*, applied his view of emergent complexity involving evolution in a higher order way, with such emergent institutional structures competing with each other and evolving as wholes competing with each other and surviving or not through a process of systemic natural selection. Some would argue that this embrace of natural selection operating at the level of higher order societal wholes constituted a contradiction with the methodological individualism of the Austrian School, although in fact in this he harked back to evolutionary ideas of the founder of that school, Carl Menger (1923) that like Hayek he fully developed late in his career.

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[21] See also Stokes (1995).

2.11 Old and New Institutional Economics from a Complex Evolutionary Perspective

The old and the new approaches to institutional economics have long been viewed as in deep conflict, with the evolutionary approach derived especially from Veblen of the old view in conflict with the greater acceptance of neoclassical economics asserted by the new, beginning with Coase (1937). Indeed, it was Veblen who initially coined the phrase "neoclassical economics," which he used in a pejorative manner to criticize the equilibrium approach of Alfred Marshall and others, so Coase's acceptance of this approach and effort to fit the new institutional economics into it would appear to be a deep conflict hard to overcome. The link between Veblen's idea of cumulative causation and modern dynamic complexity theory would seem to simply reinforce this disagreement between the approaches.

The central unifying concept of the new institutional economics is that of *transaction cost* and that minimizing this is the central core of how institutions and organizations form and develop. Whether a firm outsources an activity or carries it out within itself is determined by which of these will minimize its transaction costs as initially argued by Coase (1937), with this carried forward by Williamson (1985) and North (1990) in their more explicit formulation of the new institutional economics approach. We should note that Coase in particular, somewhat like Schumpeter, specifically rejected the direct application of biological or evolutionary ideas to his view of economics.

Even as Coase opposed the evolutionary view of the old institutional economics of Veblen, he did recognize links with parts of their views. In particular, the idea that transaction costs are important was something that he got initially from Commons (1934), with Williamson also later recognizing this source as well. As already noted, Commons took a view of institutional evolution that emphasized its directedness and its subjection to conscious human decisions, much as with the animal breeders studied by Darwin and Sewall Wright. Institutions can be consciously created by people without them simply appearing or emerging out of some mysterious dynamic process beyond human control. That this opens the door to a possible reconciliation of the old and new institutionalist approaches has been argued by Mikami (2011) who argues that even if Coase did not like biology, his views are sympathetic with sociobiology, and that the effort to minimize transaction costs can lead to a dynamic process that is complex.

2.12 Summing Up

Herbert A. Simon was the "father of behavioral economics" who formulated the concept of bounded rationality out of that. He also founded the hierarchical notion of complexity that cuts across disciplinary boundaries, which has implications for evolutionary emergence into higher level structures in nature. This goes beyond biology to a broader view of the universe, with such an emergent evolutionary process extending from emergence of atoms out of sub-atomic particles to human consciousness and beyond.

Central to understanding the complex evolution of economic institutions is fully understanding the implications of the ideas of the founder of both evolutionary economics and institutional economics, Thorstein Veblen. Particularly important was his formulation of the concept of cumulative causation, later taken up more prominently by such figures as Young, Myrdal, and Kaldor. This links to modern dynamic complexity theory through increasing returns, which leads to muiltiple equilibria and complex disequilibrium dynamics. Veblen's vision was thoroughly Darwinian in that he did not propose any directed teleological evolution in the way that favored more by fellow institutional economist, John R. Commons.

Arising from Veblen's ideas of institutional evolution is also the possibility of complex emergence of higher orders of institutions based on cooperation, linking to ideas of Herbert Simon, as well as drawing on the theory of multi-level evolution developed by biologists such as Crow, Hamilton, and Price. The existence and competition between hierarchical economic institutions also implies problems of computational complexity, again with no definite direction or outcome a likely result. This reveals the deep relations between complexity and behavioral economics.