AN AGENT-BASED THEORY OF SOCIAL ECONOMY

by

James L. Caton Jr.
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in Partial Fulfillment of
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of
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An Agent-based Theory of Social Economy

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Dedication

For my parents,
Clairann Marie Caton and James L Caton Sr.
Without your love and support, I would never have begun this project.
Nor would I have finished.

“Will you walk a little faster?” said a whiting to a snail,
“There’s a porpoise close behind us, and he’s treading on my tail.
See how eagerly the lobsters and the turtles all advance!
They are waiting on the shingle—will you come and join the dance?
Will you, won’t you, will you, won’t you, will you join the dance?
Will you, won’t you, will you, won’t you, won’t you join the dance?

“You can really have no notion how delightful it will be
When they take us up and throw us, with the lobsters, out to sea!”
But the snail replied “Too far, too far!” and gave a look askance—
Said he thanked the whiting kindly, but he would not join the dance.
Would not, could not, would not, could not, would not join the dance.
Would not, could not, would not, could not, could not join the dance.

“What matters it how far we go?” his scaly friend replied,
“There is another shore, you know, upon the other side.
The further off from England the nearer is to France—
Then turn not pale, beloved snail, but come and join the dance.
Will you, won’t you, will you, won’t you, will you join the dance?
Will you, won’t you, will you won’t you, won’t you join the dance?”

Alice’s Adventures in Wonderland
- Lewis Carroll
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All mistakes contained herein are my own.
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Abstract

AN AGENT-BASED THEORY OF SOCIAL ECONOMY

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George Mason University, 2017

Thesis Director: Dr. Richard R. Wagner

The framework of economic theory used predominantly in the post World War II era – starting with Paul Samuelson, Milton Friedman, Kenneth Arrow, and George Stigler, among others – is dependent on systems of linear equations. While these are useful for predicting outcomes with econometric models, they do not include the processes that lead to such outcomes. These models are incapable of modeling knowledge, entrepreneurship, and endogenous dynamics that emerge in the course of market interaction.

This thesis presents agent-based models that are constructed using an alternate framework. In it, action is presumed to be linked to knowledge, embodying that knowledge’s logic. Chapter 1 investigates the role of entrepreneurial strategy in overcoming search costs, where an entrepreneur’s strategy promotes structured interaction with the environment. This strategy represents technology that is cost reducing. The market selects for those strategies that most greatly reduce costs in the given environment. Chapter 2 considers the role of creativity in adaptation to change. As the environment in which market participants act changes, old strategies do not work. New strategies must be innovated to allow agents to continue to operate profitably in the market. Strategies that promote profit for agents who use them spread as they
learn from one another. Chapter 3 details the theory of knowledge upon which the models from the previous chapters depend. It considers the relationship between agent knowledge and selection of ends. It emphasizes the role of learning and plan revision and execution that lead to agent coordination across the economic system.
Entrepreneurship, Search Costs, and Ecological Rationality in an Agent-based Economy

Introduction

Over two decades ago, Gode and Sunder (1993), using a simple model of exchange, argued that equilibration in a world of voluntary exchange is dependent on a simple rule: the bid price of a buyer must be greater than the ask price of a seller. The determination of the transaction price leading to execution is of little consequence to the process of equilibration. The only requirement for equilibration is that the transaction price lie between the bid and the ask price. The authors left little role for the entrepreneur as they did not consider the impact of uncertainty and search costs on exchange and equilibration.

Using an extension of the Sugarscape model (Epstein & Axtell, 1996; Wilensky, 1999), I consider the role of transaction costs in providing opportunities for entrepreneurs to earn profits in a world where each agent acts according to unique mental structures and different circumstances. They act under conditions of asymmetric information and interpretation (Klein, 2012). The existence of costs to finding a trading partner requires agents to adopt and test production and search strategies as well as parameter values that are part of these strategies. These would otherwise be unnecessary in a world absent costs of finding a trading partner. This increases the costs of trade relative to a world where agents can trade with one another without regard to geographic distance. Entrepreneurial agents discover profit opportunities by experimentation (mutation) where they adopt new strategies for production and exchange. These strategies, when they are successful, tend to be reproduced by other agents and thereby
guide the market toward a dynamic steady-state that is akin to the static equilibrium of neo-classical theory (Kirzner, 1973, 1997).\(^1\)

**Entrepreneurship and Search Costs**

Despite their lack of recognition in the more common formulations of neo-classical price theory, transaction costs have been well recognized within the field of entrepreneurship.\(^2\) Coase (1937) formulated the firm as a nexus of contracts that helps reduce transaction costs that would otherwise exist without the firm. Economic agents find that they can avoid the costs associated with transactions in the market by participating in this contract nexus. Significantly, search costs are reduced because labor, suppliers, and customers need only contract through a single firm with a limited number of contracts. Demsetz (1988) adds to this by identifying information costs as a component of transaction costs. In this model, agent trading opportunities are limited to one’s Von Neumann neighbors. A search of the landscape for an appropriate trading partner is simply outside the realm of possibility for an agent. Furthermore, because our agent is unable to know the precise actions of other agents in advance, her only means of overcoming the uncertainty effecting the provision of resources and exploitation of trade opportunities is to adopt particular strategies to guide action *ex ante*.

In a similar vein as Coase, Williamson (1975) identifies a number of impediments to market efficiency that do not appear in a neo-classical framework that employs systems of linear equations. These include bounded rationality (Simon, 1972; Gigerenzer & Gaissmeier, 2011) and uncertainty resulting from such rationality. Human agents are not knowledgeable about all

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\(^1\) A steady-state exists when the inflow of commodities over an extended period tend to equal the outflow.

\(^2\) One exception in neo-classical theory includes Franklin Fisher (1983).
circumstances, not even all of those that are of interest to their own welfare. This uncertainty provides incentive for the creation of structures that promote a more efficient flow of information. Strategies that help overcome costs derived from limited knowledge of the agent represent opportunities for efficiency increases, and therefore, profit.

Auswald (2008, 120) argues, “transaction costs are the glue that holds together entrepreneurial new combinations.” This is true, whether they are combinations of physical capital or of strategies. Foss and Klein (2012) have presented capital combinations as being integral to the essence of the entrepreneur. They join the entrepreneur to the theory of the firm:

The reason is simple: firms are bundles of resources and entrepreneurial theory of the firm must be a theory about resources.

The authors see the entrepreneur as a controller of assets who bears costs due to uncertainty in the search for profit. As our agents are asset owning entrepreneurs, they match the description provided by Foss and Klein.

Entrepreneurship, Knowledge, and Overcoming Uncertainty

The entrepreneurial type must be considered in light of her relation to knowledge. Kirzner (1973) refers to the entrepreneur’s discovery of profit opportunities. The entrepreneur has some understanding of the world. She integrates this understanding into her actions (Mises, 1949, pp. 49, 68; Koppl, 2002; Hayek, 1962, p. 248). Understanding is reflected in the knowledge of the agent. To model the entrepreneurial function requires formulation of a theory of knowledge. Many of the pieces of such a theory have already been developed.

Foss and Klein (2012) argue that actions, not opportunities, ought to be the unit of analysis. Entrepreneurs search for possible ends given some means. While entrepreneurs do in
fact discover profit opportunities, Foss and Klein are correct that these opportunities are themselves created by entrepreneurial action. This systemic creativity, however, is an effect of the second order (Felin, Kauffman, Koppl, & Longo, 2014; Koppl, Kauffman, Felin, & Longo, 2015). Entrepreneurial effectuation implies a relatively open-ended search where agents operate under a one-to-many mapping of reality (Sarasvathy, 2001). Agent ends are not given, only the means are. Possible ends are multitudinous. In our model, the determination of agent ends is provided by the rules that govern behavior. Actions are determined by a component of a classifier (Holland, 1992) that select from given ends. That end is determined in light of given means and environment of the agent. The means is the behavioral rule and any objects that rule may employ. Integrated into its structure are agent abilities.

The agent relies on understanding, or knowledge represented by her mental model (Denzau & North, 1994; North 2005). This model is an agent’s personal ontology (Nonaka, 1994; Cioffi–Revilla, 2014). This ontology is comprised of representations of the ecology she helps comprise: objects in the environment, relationships between the objects, and processes that transform those processes (Wagner, 2010; Pratten, 2014).

The agent herself plays a role in this mental model. Objects not only have a relationship with one another, but also may have a relationship with the perceiving agent. An example helps to clarify. An agent in our model may identify sugar on a patch. The agent, by means of her rule of behavior recognizes that she could come to possess that sugar. Further, upon possession, she may transform part or all of the sugar by consuming it. The agent must choose which potential reality to fulfill. The rule not only helps the agent conceptualize the relationship between herself

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3 At the next higher level of abstraction, the market, profit and loss select out unsuccessful strategies and retain strategies that promote success.
and the sugar, but brings into realization one of those potential realities by determining the agent’s course of action.

A caveat inherent in agent-based modeling must be noted. The agents do not have free will. Rather, the human or humans who program the model selects the behavioral rules available to the agents. The rules order the preferred ends of the agent in terms of some valuation and, thus, determine action (Mises, 1913; Booker, Goldberg, & Holland, 1989). To this extent, an agent-based model is an extension of the programmer’s will. The ultimate effects of that will are not possible to know ex ante. The behavior space is vast (Dennett, 2008) and reality is only revealed after the agent acts. Although these agents are, in effect, robots, their action contains some element of human action. As the agents act toward ends determined by some scale of values, this “quasi-action” (Mises, 1949, pp. 23–28) represents a manifestation of a category of action that Koppl (2002) identifies under the heading of acognitive expectations.

Apart from the fact that in the real world quasi-action occurs within an open system, general form of the logic governing this type of action is not different from that of the automatons programmed into the “game of life” (Beer, 2004). In order to make decisions that lead to patterned action, agents must follow clearly defined logic that can be described as knowledge (Hayek, 1962). This knowledge exists as a plurality of if-then statements that are executed serially and consider arrangement and values of objects familiar to the agent.

Not all knowledge is useful. Knowledge is only useful to the extent that 1) it helps the

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4 Mises refers to this as “quasi-action”:
We observe two things: first the inherent tendency of a living organism to respond to a stimulus according to a regular pattern, and second the favorable effects of this kind of behavior for the strengthening or preservation of the organism’s vital forces. If we were in a position to interpret such behavior as the outcome of purposeful aiming at certain ends, we would call it action and deal with it according to the teleological methods of praxeology.
agent overcome uncertainty that appears to follow some identifiable pattern. It helps them overcome *ontological uncertainty* (Lane & Maxfield, 2005). This type of uncertainty is a component of Knightian risk as it can be identified and overcome with the appropriate knowledge (Knight, 1921). The system must have some means of selecting rules that promote action that supports agent survival and discarding rules that do not. A rule structure that represents coherent understanding of the objective environment, which includes other agents, represents useful knowledge. It allows agents to increase the chance of survival (Alchian, 1950; Gigerenzer, 2008; Rosser, 1999, p. 183).

A selection process that tends to identify and retain superior rules underlies the core of a self-ordering economy. Just as in biological evolution, competition provides the selection mechanism (Young, 1998; Gintis, 2009). Unlike in biological evolution, random mutation is not the driving force behind change in the economic system. By her creativity, the entrepreneur provides contributions to knowledge that are tested by competition. In one manner or another, this knowledge is often made public to, and therefore available for use by, other agents. Some agents exhibit knowledge that supports their ability to identify and imitate existing knowledge that promotes agent survival (Hayek, 1962; Carayannis, Provance, & Grigoroudis 2016; Bikhchandani, Hirshleifer, & Welch, 1998; Li & Tesfatsion, 2012). This process of transmission sometimes occurs with error that may or may not be beneficial to the agent (Earl, Peng, & Potts 2007). By this transmission mechanism, knowledge of beneficial behaviors can spread quickly after its discovery and agents can collectively overcome uncertainty (Lavoie, 1995).

This appeal to trial and error is not merely a theoretical assertion. Real world entrepreneurs (for the remainder of this paragraph we refer to the social, as opposed to functional, type of entrepreneur) have identified precisely this mechanism of knowledge
generation. Many entrepreneurs practice strategies where they attempt to maximize experimentation among their investments, selecting those innovations that are profitable and discarding those that are not (Kerr, Nanda, & Rhodes-Kropf, 2014). This strategy has become so common that the phrase, “fail fast”, has become mantra among many entrepreneurs (Brown, 2015). Kerr, Nanda, and Kropf (2014) observe that from their sample, 6 percent of startups “accounted for about 50 percent of the gross return (2014).” This process of experimentation appears to be at the root of skewed wealth structure in society where “a few outliers account for a disproportionate amount of the entire distributions output” as “more than 60% of all new jobs are created by a mere .03% of all entrepreneurial start-ups (Aguinis, et. al., 2015, 697; see also Crawford, McKelvey, & Lichtenstein, 2014).” This holds true for the model presented below as strategies from the earlies generation tend to be outcompeted by those who discover more efficient strategies.

The Sugarscape Economy

Epstein and Axtell’s Sugarscape stands as the canonical model for exploration of the capabilities of simulation of societies through agent-based modeling. In Growing Artificial Societies, Epstein and Axtell (1996) investigate the nature of production and exchange as well as warfare and epidemics. Like Axtell (2005), the authors borrow from neoclassical standard of rationality whereby agents maximize a utility scalar by their decisions that lead to action. While agents do make decisions that they believe will result in the most preferred state of reality (Menger, 1976), dependence on scalar utility is an artifact that we inherit from the Walrasian paradigm. Advances in the understanding of cognition and decision-making, like those

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5 As of March 8, 2016, Google Scholar identifies that Epstein and Axtell (1996) has been cited 4240 times.
mentioned above, present an opportunity for a new avenue of exploration and understanding.

Perhaps due to the audience receiving their work, Axtell and Epstein did not go on to investigate decision-making rules other than standard utility maximization. In reflecting on the meaning of their work, Axtell and Epstein recognize this space for development:

... Artificial society models permit a more evolutionary outlook: Instead of assuming behavioral rule, there could be a population of rules in society. One might specify this rule population at the outset [Arthur 1994] or have agents invent their own rules using genetic algorithms, genetic programming, or neural networks. But however one generate the rules, some rules enjoy differential survivability (emphasis authors’) over others – after a long time one observes more agents following rule i than rule j. This really is all we can operationally mean when we assert that rule i enjoys a selective advantage over, or is ‘fitter than,’ rule j [emphasis mine]. (162)

The rules employed in this model of Sugarscape draw information from the environment as a guide for agent activity. Absent assistance from technology, there is an upper limit to the processing power of the human mind (Simon, 1974). For this reason, agents make prediction according to the observed structure of processes in their environment. This type of strategy is efficient as it reduces the computational requirements of the agent, often without significantly reducing the value of affected outcomes compared to neoclassical utility maximization (Czerlinski, Gigerenzer, & Goldstein, 1999). This formulation of a realistic cognitive framework, often described as ecological rationality (Smith, 2003), must remain underappreciated as long as such a mode of operation is not explicitly investigated and implemented with regard to both the individual agent and interactions between multiple agents.

**Agent Class.** In this rendition of the model, entrepreneurs are treated as firms (Foss & Klein, 2012). These agents make decisions according to standards categorized by different 

---

6 Thus we should think of the death of an agent as equivalent to the bankruptcy of a firm.
classes. There are two primary classes: Basics and Switchers. Each of these can be augmented by the Herder and Arbitrageur classes. The classes are described below.

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<tr>
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</tr>
<tr>
<td>Herder</td>
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<td>Arbitrageur</td>
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**Basic.** A Basic agent follows a unique instance of the original rule used in Wilensky’s version of Sugarscape. In it the agent moves to the patch that has the greatest amount sugar. In event of a tie for this measure, he chooses randomly from those patches closest to him. Agents in these experiments can only see as far as one patch away from their location. The agent does not differentiate between resource types.

**Switcher.** Like the Basic, the Switcher moves to the closest patch with the highest resource value. Unlike the Basic, the Switcher searches for only one type of good at a time. The agent alternates between searching for each good for some period of time whose value is drawn from a uniform random distribution.

**Herder.** The Herder copies the attributes of the richest agent with whom she has come into contact. This assumes that this information is locally available – in other words, agents share information with one another. While this is not always true in reality, it is a useful assumption to employ in order to understand the core dynamics that arise due to the flow of information between agents. Outcomes are thus dependent upon the rule composition of the population within which the herding agent operates.
**Arbitrageur.** The Arbitrageur remembers past transaction prices. She mines for the good that is, on average, more valuable given her belief in some expected price that she has formed for each good. Unlike other agents, the Arbitrageur integrates information that allows her to immediately respond to the needs of her peers. While it is in the Arbitrageur’s interest to mine for the more valuable good, the Arbitrageur also serves the interest of society by doing so. A commodity price that rises above the price that incites a response from the Arbitrageur indicates the agent that the commodity is undervalued and incentivizes her to extract that commodity. An individual arbitrageur may believe incorrectly that a good is overvalued or undervalued. To the extent that she is wrong, the market will tend to allocate less resources toward that agent.

**Prices and Exchange.** Agents interact with their environment by means of rules structure associated with each class. Interaction with the environment does not necessarily promote economic coordination. Agent action must be influenced by prices to promote this. These prices are one means by which knowledge is transferred between agents. They comprise a “telecommunication system” (Hayek, 1945). An agent’s decision to purchase more or less of a certain good tends to influence the relative price of the good, and thus communicate changes in relative scarcity. This provides a standard for agents to determine which good to produce and incentive to limit their consumption of more scarce goods. It also guides agents’ decisions concerning whether or not to produce the good. The change in price in a world of many goods, inasmuch as it represents a change in relative price, will go on to influence the price of complements and substitutes, as well as inputs required for the good’s production and outputs for which the good serves as an input (Hayek, 1935). Even when agents are not conscious of this change, plans that do not cohere with the price change will tend to be ill-suited for the
environment.

**Barter Algorithm.** The barter algorithm assumes agents to be of equal stature in terms of bargaining power. The basic structure for this interaction is adopted from Gode and Sunder (1993). Agents each value a good at a particular price. If the bid-price of the agent demanding the good is higher than the ask-price of the agent selling the good, a random value is chosen within the range supplied by the agents. In our model, the agents are bartering directly. To ensure that the algorithm does not favor either the buyer or the seller, the uniform distribution is chosen from the range of the logged value of prices supplied by the buyer and seller. The value chosen is then converted back to the actual value by un-logging the logged value of the final transaction price. We describe it with the following three components: target reserve levels, the pricing algorithm, and the exchange algorithm.

**Target Reserve Level Distribution.** Every agent must choose a target reserve level for sugar and water. Random values are selected from a uniform distribution. The target reserve level provides a standard for the agent to adjust the price reflecting their willingness to pay and willingness to accept.

**Pricing Algorithm.** Agents adjust their bid and ask price for sugar according to the algorithm:

\[
\Delta p_{g_0,t_1} = \alpha (\ln(T_{g_0,t_0} / q_{g_0,t_0}) - \ln(T_{g_1,t_0} / q_{g_1,t_0}))
\]

*Equation (1.1)*

Where:

\[
\Delta p_{g_i,t_p} = \text{Change in the Price of Sugar at Period } p \\
T_{g_i,t_p} = \text{Target Reserve Level of Good } i \text{ at Period } p \\
q_{g_i,t_p} = \text{Quantity of Good } i \text{ held at period } p
\]

An agent’s willingness to pay for a good increases if the quantity of goods that the agent desires
– as defined by the target water and sugar reserve levels – is higher than the quantity of the good possessed by the agent. Likewise, if the agent possesses an excess amount of the good, she will decrease the price that she is willing to accept (or provide) for the good. Under the dynamic pricing rule, the magnitude of the price change increases as the agent’s actual stock of goods deviates from the target level. The amplitude of price changes is moderated by use of the randomly determined scalar, \( \alpha \). As with strategies and other parameters, values that promote agent survival tend to be selected for. One can imagine other rules for setting an agent’s bid-ask price. Again, competition selects an efficient composition of rules on a given landscape.

*Exchange*

When two agents meet, they compare their bid and ask prices. If the bid price of the buyer is greater than the ask price of the seller, a price is chosen randomly from the range using a function defined:

\[
p = e^{(\ln(p_a) + (\lambda(\ln(p_b) - \ln(p_a)))}
\]

*Equation (1.2)*

Where:

- \( p \) = transaction price
- \( p_a \) = Ask Price of Selling Agent
- \( p_b \) = Bid Price of Buying Agent
- \( 0 \leq \lambda \leq 1 \)

The price is chosen from a logged random-uniform distribution. This allows, on average, for the price chosen to be closer to the mean of the bid and the ask price than if the distribution was not logged.

*Expected Price (Arbitrageur only).* The expected price of sugar (which is the inverse of the expected price of water) guides the Arbitrageur’s production decisions. This expected price is chosen from a random distribution. Values that do not promote the survival of the
entrepreneur are selected out from the population.

Agents compete with one another by employing particular instances of class and pricing strategies. The fitness of these strategies depends not only on the landscape, but on the strategies chosen by other agents. As the environment is often in flux, some strategies may be more fit during some periods of a run than others. Only by the process of trial-and-error are more efficient combinations selected over less efficient ones given some context.

**Strategy, Action, and Survival**

Agents face a vast array of combinations of decision-making protocol and parameter values. The survivability of each of these combinations can be described in terms of their ability, on average, to lower search costs for the agent who adopts them. For every possible state in the behavior-space, there exists an expected cost for each agent to find a trading partner given their class and parameter values:

\[
E(C_T) = (E(d) / v) \times (C_s + C_w)
\]

*Equation (1.3)*

Where:
- \(E(C_T)\) = expected cost of finding a trading partner with the desired good
- \(E(d)\) = expected distance traveled
- \((E(d) / v)\) = expected span of time to find a trading partner
- \(C_s\) = rate of sugar consumption per period
- \(C_w\) = rate of water consumption per period

Agent wealth is described as the agent’s current stock of goods and the expected stream of goods between period \(t\) and period \((t + \tau)\):

\[
E(W_{t + \tau, 0}) = q_s + q_w + (E(s + w) - (C_s + C_w)) \times E(\tau)
\]

*Equation (1.3)*

Where:
- \(E(W_{t + \tau, 0})\) = expected wealth immediately prior to exchange
- \(q_s\) = agent’s stock of sugar at time \(t\)
\[ q_w = \text{agent’s stock of water at time } t \]
\[ E(s + w) = \text{expected rate of water and sugar inflows per period} \]
\[ E(\tau) = (E(d) / v) \]

We transform the equations, replacing the current quantities and expected flows with expected quantities at time \( t + \tau \):

\[ E(q_{s,t + \tau,0}) = q_s + (E(s) - (C_s)) \times E(\tau) \]
Equation (1.4a)
\[ E(q_{w,t + \tau,0}) = q_w + (E(w) - (C_w)) \times E(\tau) \]
Equation (1.4b)

If \( E(q_{s,t + \tau,0}) \leq 0 \rightarrow \text{Agent shuts down operation on average} \)
Equation (1.5a)
If \( E(q_{w,t + \tau,0}) \leq 0 \rightarrow \text{Agent shuts down operation on average} \)
Equation (1.5b)

Where:
\[ E(s) = \text{expected rate of sugar inflow per period} \]
\[ E(w) = \text{expected rate of water inflow per period} \]
\[ E(q_{s,t + \tau,0}) = \text{expected stock of sugar immediately before trade} \]
\[ E(q_{w,t + \tau,0}) = \text{expected stock of water immediately before trade} \]

If expected costs of finding a trading partner are less than the sum of present income and expected income flows, the agent will not survive on average. If expected costs are less than these, then the agent will become wealthier on average. Over many runs, if one particular class of agents tends to perform better than others, the agent class, given their discovery of profitable arrays of parameter values, is more fit than other according to the logic of these equations. Successful strategies will tend to reduce the costs borne by agents who follow the respective strategy. To the extent that the strategy produces profits (\( TR > TC \)), the strategy will be duplicated through reproduction by the agent. If it generates a greater level of success than that of competing agents, the strategy will tend to be duplicated by trading partners of the herder class.

Agents trade goods. Thus far, equations have included the costs of finding a trading
partner without including the price associated with a trade. All executed exchanges are subject to some price that is set between the bid and ask prices of each agent. The equations below include expected transaction price. Equations 1.6a and 1.6b represent cases where the agent has enough of one good to match the stock of the good in which she is deficient to the target level. Equation 1.7a and 1.7b represent the case where an agent has excess of one good, but not enough to move the stock of the other good to its target level. In the last case (equation 8) trade will not occur until the agent accumulates excess of one good:

\[
\text{If } T_w - E(q_{w,t + \tau,0}) \leq (q_{s,t + \tau,0} - T_s) / p_s:
\]

\[
E(q_{w,t + \tau,1}) = E(q_{s,t + \tau,0}) - (p_w)(T_w - q_{w,t + \tau,0})
\]

Equation (1.6a)

\[
\text{If } T_s - E(q_{s,t + \tau,0}) \leq (q_{w,t + \tau,0} - T_w) / p_w:
\]

\[
E(q_{s,t + \tau,1}) = E(q_{w,t + \tau,0}) - (p_s)(T_s - q_{s,t + \tau,0})
\]

Equation (1.6b)

\[
\text{If } T_w - E(q_{w,t + \tau,0}) > (q_{s,t + \tau,0} - T_s) / p_s:
\]

\[
E(q_{w,t + \tau,1}) = E(q_{s,t + \tau,0}) - (p_w) * (T_w - q_{w,t + \tau,0})
\]

Equation (1.7a)

\[
\text{If } T_s - E(q_{s,t + \tau,0}) > (q_{w,t + \tau,0} - T_w) / p_w:
\]

\[
E(q_{s,t + \tau,1}) = E(q_{w,t + \tau,0}) - (p_s) * (T_s - q_{s,t + \tau,0})
\]

Equation (1.7b)

\[
\text{If } T_s - E(q_{s,t + \tau,0}) > 0 \text{ and } T_w - E(q_{w,t + \tau,0}) > 0:
\]

No trade expected

Equation (1.8)

Where:

\( T_s \) = target stock of sugar

\( T_w \) = target stock of water

\( E(q_{s,t + \tau,1}) \) = expected stock of sugar immediately after trade

\( E(q_{w,t + \tau,1}) \) = expected stock of water immediately after trade

\( p_s \) = price of sugar in units of water

\( p_w \) = price of water in units of sugar

---

7 One could imagine arrangement where an agent attempts to match the ratio of target reserve levels to consumption ratios or any number of other strategies. This represents an unexploited profit opportunity that I invite others to explore.
The reader should note that in the above exposition, we treat expectation differently than it is
has traditionally been used in economics (Muth, 1961; Fama, 1970; Sargent, 2014). Expectation
in equations 1.1-8 represent a Bayesian interpretation where agents need not be aware of the
expected value of a strategy that occurs at the system level. The rate of survivorship indicates
whether the expected value of a combination of strategy and parameters are positive given
some state of the model. Agent expectations are defined by this strategy and parameter
combination.

Results
To observe the effect of cost-reducing technology, model runs are divided into three separate
cases. In the first case agents trade locally and use only Basic strategy. Agents may only trade
with Von-Neumann neighbors. In the second case agents trade globally and use only Basic
strategy. Agents are paired automatically with another agent who has surplus of the desired
good. In the third case, agents face costs of finding a trading partner and can use any
combination of strategies and parameters described above. The first and second cases represent
the bounds of the experiment, against which the third case is compared.

Table 1.2

<table>
<thead>
<tr>
<th>Simulation Cases</th>
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</thead>
<tbody>
<tr>
<td>Agent Class</td>
</tr>
<tr>
<td>Case 1</td>
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<tr>
<td>Case 2</td>
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<tr>
<td>Case 3</td>
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</tbody>
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For each case there is taken the average value of a given parameters and variables at period
15000. These represent approximations of long-run conditions, and therefore equilibrium
values, in the model. Results are presented in the form of heat maps where each square
represents the average value of a variable that is endogenously determined across 10 different
runs. The x and y axes represent the consumption rates of water and sugar respectively. Tables
include the values of population (Figures 1.1-3), the price of sugar\(^8\) and its variance (Figures 1.4-9), class population reported as proportion of the entire population (Figures 1.10-13), and
wealth per capita of the entire population as well as among class populations (Figures 1.14-16, 1.17-20).

**Population as Welfare Measure.** The clearest indicator of economic health in each set
of experiments is the population of agents. The welfare level of the system, as reflected by
population tend to be highest in the case where each agent is automatically paired with a
trading partner regardless of her geographic positions (Figure 1.2). Likewise, welfare levels are
their lowest when agents face these costs and use only Basic strategy (Figure 1.1). The
integration of new strategies into agent decision-making increase welfare across the behavior
space. Under most circumstances, population levels are either as high or nearly as high as in the
case where there are no trading costs (Figure 1.3). Given objective conditions faced by the
agents, i.e., the needs of each agent as represented by consumption rates, the level of
population is dependent upon the ability of that population to maintain minimal flows to each
agent. In a dynamic equilibrium, inflows of goods into the economy tend to equal outflows.
Thus, an increase in the long-run level of population is equivalent to an increase in the flows of
these resources.

A pattern emerges across each of the three cases. As either consumption rate increases,

\(^8\) The price of water is the inverse of the price of sugar
the equilibrium level of population falls. Population falls as the costs of action increase. The number of agents that employ these goods falls as the price of either input rises just as the number of firms in an industry decrease when input prices increase.

**Figure 1.1. Population – Local Trade – Basics**

**Figure 1.2. Population – Global Trade – Basics**

**Figure 1.3. Population – Local Trade – All Classes**
**Prices, Profit and Entrepreneurial Niches.** Figures 1.4-6 compare the mean prices that emerge for each case. Prices in both the local and global cases that include only Basic agents are more tightly constrained than in the remaining case where agents use diverse strategies. The increase in variance occurs when consumption rates tend to be more similar as multiple strategies are present on the landscape (Figures 1.6 and 1.9). There is much less variance in the runs that lack diverse strategies (Figures 1.4, 1.5, 1.7, and 1.8).

As conditions change, different classes of agents fill niches that emerge, leading to a variety of types of outcomes across the behavior space. When consumption ratios are more similar, prices play a less significant role in coordination than in cases where consumption rates for each good are less similar. Both the Basic and Switcher strategies, when not augmented by the Arbitrageur strategy, tend to promote rates of harvesting for each good that are similar. Arbitrageur agents tend to perform poorly compared to non-Arbitrageur agents in this class of scenario (Figure 1.11-13). As consumption rates deviate from one another, however, the society requires an increase in the flow of the good that is consumed at a higher rate. Arbitrageurs agents promote this outcome as reflected by a strong correlation between their presence and a decrease in price variance (compare Figures 1.9 and 1.13). Arbitrageurs respond to prices. Those that survive tend to gather the good that is scarcer.

**Population and Wealth Per Capita.** Wealth per capita is highest in the most impoverished case: local trade with only Basic strategy (Figure 1.14). This does not reflect that the society that practices only Basic strategy under conditions of local trade has the highest level of general welfare. Recall that a lower level of population reflects diminished flows of goods relative to circumstances with a higher level of population. The impoverished society represented by the case of local trade with only Basic strategy reflects an inability for poorer
agents to trade with wealthier agents for goods necessary to their survival.

Similar results hold for the cases of global trade with only Basic strategy and local trade with all strategies present (Figures 1.15 and 1.16). There exist discrepancies between these two cases when consumption rates for each good tend to diverge. Where there exists no cost to transporting goods between trading partners, this divergence has little effect on the level of wealth per capita. When consumption rates diverge, population levels and wealth per capita tend to be higher in the case of global trade with only Basic strategy relative to a society with local trade and all strategies. Finally, these results suggest that competition and cost-reducing innovation tends to spread wealth necessary for survival to a greater span of the population.

Failure to reduce the costs of economic activity promote the opposite effect. Lower levels of population are associated with higher costs of activity and impoverishment of those agents who fail to survive. An increase in the costs of economic activity not offset by cost-reducing technologies promotes higher levels of wealth concentration and impoverishment.

**Macrostability and Microvolatility.** The process of equilibration itself requires guidance from disequilibrium conditions as disequilibrium represents a profit opportunity; it represents an available niche in the market (Kirzner, 1973; Fisher, 1983). Entrepreneurs attempt to discover and exploit these. Whatever niche is to be filled, those capable of filling it are retained to fill the niche by their earning above-normal rates of profit. One might be surprised to see the term “normal profit” in reference to a model that does not assume equilibrium conditions. However, the model does generate equilibrium-like persistent states where average rate of return for each strategy tends to converge to a narrow range of values. The patterns of returns that emerge support the equimarginal principal as an ex post outcome generated by the system, consistent with a general discussion of emergence in economics by Harper and Lewis (2012, p.
This does not suggest that, *ex ante*, all agents optimize in correspondence with this principle. The system selects for agents who use strategies that efficiently exploit the landscape. The optimizing reflected by the neoclassical system is forced upon competitors by the competitive system. The only other option is bankruptcy.

There emerges from the model nearly identical levels of wealth per capita across classes and combinations of consumption rates that result from a process of trial, error, and strategic duplication of strategies by agents (Figures 1.18-20). When the system is in stasis, agent classes that successfully sustain substantial population levels exhibit market rates of return as defined by wealth per capita. Basic agents do not exhibit this tendency when competing against Switcher agents. In the long run this population is practically non-existent when forced to compete with Switcher Agents. Figure 1.23 shows that the average wealth per capita within the Switcher class broadly defined\(^9\) tends to equalize once the system has reached a stasis.

Stability in one average statistic does not imply stability at all levels of the system (Wagner, 2010, 2012). There exists macro level stability that coincides with orderly chaos within the economy. As long as entrepreneurs continually exploit profit opportunities generated as second order effects of action by other agents with the system, this macro stability may be maintained (Koppl, et al., 2015). The composition of the population as defined by class affiliation is almost always in flux within the model as new profit opportunities attract entrepreneurs suited to exploit them, and thus earn supernormal profit as long as the niche remains available (Figures 1.21-23). We observe strong correlations between different classes of agents. Successful entrepreneurs correctly predict the oversupply and undersupply of goods that result

---

\(^9\) This includes non-augmented Switchers, Switcher Herders, Switcher Arbitrageurs, and Switcher Herder Arbitrageurs.
from the systematic behavior of others in this society. These correlations are by no means permanent in character. They do indicate changes in the composition of niches available for exploitation by entrepreneurial agents.

Finally, Figures 1.21-24 do not show all information pertaining to agents. Agents not only adopt 1 of 8 possible strategy combinations, but must also choose from parameters governing their switching rate, the nature of their response to prices, the rate at which agents adjust bid and ask prices, and so forth. Even reduced to a lower level of dimensionality defined only by the strategy used, changes in strategy composition alone suggest interaction between agent strategies as well as between those strategies and the environment.

![Figure 1.4. Average Prices – Local Trade – Basics](image1)

![Figure 1.5. Average Prices – Global Trade – Basics](image2)
Figure 1.6. Average Prices – Local Trade – All Classes

Figure 1.7. Price Variance – Local Trade – Basics

Figure 1.8. Price Variance – Global Trade – Basics
Figure 1.9. Price Variance – Local Trade – All Classes

Figure 1.10. Percent Basic – Local Trade – All Classes

Figure 1.11. Percent Switcher – Local Trade – All Classes
Figure 1.12. Percent Herder – Local Trade – All Classes

Figure 1.13. Percent Arbitrageur – Local Trade – All Classes

Figure 1.14. Wealth Per Capita – Local Trade – Basics
Figure 1.15. Wealth Per Capita – Local Trade – Basics

Figure 1.16. Wealth Per Capita – Local Trade – All Classes

Figure 1.17. Basic Wealth Per Capita – Local Trade – All Classes
Figure 1.18. Switcher Wealth Per Capita – Local Trade – All Classes

Figure 1.19. Herder Wealth Per Capita – Local Trade – All Classes

Figure 1.20. Arbitrageur Wealth Per Capita – Local Trade – All Classes
Figure 1.21. Wealth Per Capita – Primary and Secondary Classes

Figure 1.22. Wealth Per Capita – Switcher Classes
Figure 1.23. Class Affiliation as a Percent of Population – Primary and Secondary Classes

![Class Affiliation as Percent of Population](image)

Figure 1.24. Class Affiliation as Percent of Population - Switcher Classes

![Class Affiliation as Percent of Population](image)
Implications

Competition between agents employing different strategies and parameter sets tends to promote patterns of action that overcome search costs and efficiently exploit gains from the landscape given the knowledge available to agents. The addition of entrepreneurs with different class strategies tends to increase the efficiency of production and exchange. This is confirmed by comparison of economic activity in the case where agents use only Basic strategy against the case of local trade and competing technologies. The introduction of additional strategies increases the landscape’s carrying capacity by allowing agents to more efficiently gather and trade resources. The composition of strategies on the landscape are determined by the rate of return associated with the strategy. The population of a class tends to increase until the average rate of return of the class meets the market rate of return. Agents using them can better predict changes in the landscape and thus act in a manner that promotes their survival. Further, under conditions where prices that fail to reflect scarcity reduce the welfare of the system, there exists profit opportunities for Arbitrageurs, agents who use strategies that might exploit the imbalance for gain. This results in an improvement in welfare of the system as reflected by population levels.

Put simply, agents profit most by targeting goods that are, at the present state, undersupplied. The strategy of Basic agents is especially inefficient in accomplishing this as compared to other classes of agents. Production by Basic agents fails to respond directly to prices and fails to find means to systematically target resources that are most highly valued. For this reason, they are outcompeted in the presence of Switcher and Arbitrageur agents. Switcher
agents, by virtue of collecting both water and sugar target the scarcer resource half of the time. Arbitrageur agents respond to price. They accomplish the task with greater efficiency than Switcher agents under conditions where consumption rates diverge.

As Yang and Chandra (2014) as well as Koppl, et al., (2015) argue, the agent’s environment includes other agents. Therefore, the success of an agent and the agent’s nature itself is dependent upon the nature of other agents in the environment against whom they compete. The strategy of an entrepreneur may promote success under certain conditions and failure under others. Consistent with the equimarginal principle, super-normal profits are competed away as one entrepreneur’s niche is displaced by similar competitors or the innovation of a competing strategy.

Conclusion

This paper makes several contributions. It presents a framework for modeling entrepreneurial decision-making and, therefore, entrepreneurial action that is ecologically rational. Such a model has allowed for investigation of an aspect of entrepreneurship which, to this time, could not be satisfactorily investigated using analysis dependent upon systems of linear equations. This model provides means to investigate the relationship between cost and the structure of entrepreneurial strategy. In overcoming these costs entrepreneurs profit and improve the welfare of the system.

One need not assume equilibrium as economic teleology. An equilibrium-like persistent state is a phenomenon that emerges in particular domains of observation. It is a phenomenon that emerges due to the interaction of agents and the environment under conditions of disequilibrium. I hope that this construction and its results might encourage economists to employ their creative energies to model what, to this time, could not be formalized.
Citations


Creativity in a Theory Entrepreneurship

Introduction

. . . a central difference between my dog and any one of us lies in his lack of any sense of becoming different from what he is. . . But we, as human beings, also know that we can, within limits, shape the form of being that we shall be between now and the time of death.

James M. Buchanan, “Natural and Artifactual Man”, 1979

Humans act. They apply given means toward some end of their choosing (Sarasvathy, 2001). The environment in which a person acts is bound to change over time, often in ways that are unpredictable. Frank Knight (1921) identifies the entrepreneurial role as one of overcoming uncertainty that may otherwise prevent him and others from achieving desired ends. The entrepreneur exerts energy in confronting and preparing for situations about which he may not have full or even partial knowledge. Just as the environment changes, so too does the acting agent. Reflecting on this, Buchanan reconsiders Heraclitus, saying “Man does not step into the same river twice, first, because the stream has passed, and, second, because man too has moved forward in time [emphasis mine] (Buchanan, 1979, p. 257).” An essential element of human action is man’s quest to change his own beliefs, or more fundamentally, his own character. These are reflected in a change in his pattern of action. To adapt to changing circumstances simply by one’s own effort is a uniquely human characteristic. Man is an object of his own analysis. He is creative.
The human agent’s understanding of the environment is embedded in strategy: patterns of action aimed at some end. Strategy that drives agent action interacts with prices. These play a vital role in coordinating the social system. Some theorists, in the mode of Becker and Stigler (1977), attempt to explain all action in terms of prices. This framing of human action, however, is unable to observe the fundamental role that sensing entrepreneurs play in producing innovation and transforming the economic system (Kirzner 1973). As entrepreneurs become aware of new possibilities, they disrupt the old order (Schumpeter 1912) and recoordinate the system in light of the new innovation, moving it to a new persistent, equilibrium-like state. Such entrepreneurial activity calls for “aggressive, bold, creative, leadership qualities” that bring the fruit potentiated by entrepreneurial alertness into existence (Kirzner 1999, 13). Whether the shock to the economic system that was previously in a coordinated state comes from innovation or less beneficial disruption, entrepreneurs work to move the system to an efficiently-coordinated state in light of knowledge of this disruption. Successful entrepreneurs adapt to changing circumstance that includes changing knowledge, preferences, and prices that result from these.

The entrepreneur and entrepreneurial adaptation are non-existent in the core model of neoclassical economic theory (Baumol 1968; Kirzner 1963a; Buchanan 1991) as equilibrium is not a result, but an assumption of the model (Debreu 1959; Arrow and Hahn 1971; Muth 1961; Fama 1970; Axtell 2007, 107; Wagner 2010). Rather than being defined by ecologically dependent rules, agent knowledge is reduced to a utility function. The theoretical agent is left to make decisions in response to changing prices according to optimization calculus. Over the course of the last half-century, alternative framings of the economic agent have been generated (Simon 1969; 1972; 1974; Hayek 1962; Smith 2003; Gigerenzer 2008), but these have not been
synthesized in a manner that joins a systematic theory with felicitous modeling comparable to econometric analysis or dynamic stochastic general equilibrium models.

Below, I construct an economic agent in light of literature discussing entrepreneurship and creativity and apply this construction to an agent-based model. I use a heuristic rendition of Sugarscape (Epstein and Axtell 1996; Wilensky 1999) with two goods, sugar and water, to show that creativity is generated by the agent and is regulated by a system subject to competitive pressures. These competitive pressures often lead to emergent patterns. For example, in some cases agents of a particular class will cluster on one side of the landscape while population of a different class or classes divide evenly between the sugar and water sides of landscape.

The model follows the framework laid by Yang and Chandra (2013) who suggests that agent-based models are ideal for investigating competition and strategy present in an evolutionary theory of entrepreneurship. Similarly, this work follows McKelvey (2004) who suggests that agent-based computation is essential for the study of order formation, as opposed to the study of equilibrium. He also suggests that processes be identified where agents can make educated guesses.10 The Sugarscape agents have some array of strategy structures and parameters that they alter by experimentation and which are adopted by agents who prefer to copy others who have proven their success. Strategies are ultimately selected by the competitive process. When a system reaches a persistent state, creativity, as defined by this experimentation, settles to a relatively low level. However, if this system is upset by an exogenous shock, agents increase their creativity on average. Successfully adaptation to the new environment occurs by a process of trial and error, forming a new regime of coordination.

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10 Agents in our model do experience blind variation alongside strategic copying of strategies from successful agents.
Entrepreneurship and Knowledge

The entrepreneur acts to improve his future state of well-being (Mises, 1949; Lewis, 2016 cites Shackle, 1979). In this sense, we are all entrepreneurs. In the context of a market system, entrepreneurs act as directors of production whose efforts are guided by monetary profits (Cassell, 1932, 171). Within a market ordering successful entrepreneurs accommodate and even influence the desires of consumers. Entrepreneurs must discover profit opportunities as they act in a world that changes in ways that are difficult, if not impossible, to predict (Knight, 1921).

The entrepreneur is endowed with a stock of resources. Her job is to use the resources in a manner that increases the value of her total holdings. The entrepreneur has some given means and must determine toward which ends they will be employed and how they will be employed for this purpose (Sarasvathy, 2001). In the process of choosing and accomplishing an end, the entrepreneur will likely acquire intermediate ends in the service of her ultimate end. These are means to realizing the ultimate end. They may include objects such as a semi-truck used to transport goods from suppliers to retailers, or they may include more abstract goods.

In this sense, knowledge is an economic good. It is a means to action and coordination. Knowledge is scarce and may be deemed by economic agents as having positive value. Ken Arrow explains:

Uncertainty means that we do not have a complete description of the world which we fully believe to be true. . . . Our uncertainty consists in not knowing [emphasis mine] which state [of the world] is the true one. (1974, 33-34)

If one is able to reduce ontological uncertainty (Lane and Maxfield, 2005) by means of acquiring useful knowledge, she has moved into a state of the world where she can more efficiently order her actions in light of her ends. Knowledge of this sort generates value for the economic actor as
it improves her ability to bring desired end states into realization. In our model such knowledge exists as new strategies or routines – behavior definable by a set of rules (Nelson and Winter, 1982; Nelson and Winter, 2002, 30; Dopfer and Potts, 2004, 198) – and parameter values that help those who adopt them survive. The level of success that these strategies will promote is not known \textit{ex ante}, but agents learn rules that tend to promote sufficient adaptation for survival (Macmillan and Low, 1988).

While knowledge may be acquired without a market transaction, there exists positive cost to acquire or transfer knowledge. Certain types of knowledge may be scarce even when their explicit presentation is of miniscule cost. The average consumer would not know how to interpret Einstein’s theory of relativity, though he or she could access it at only scant marginal cost if an internet connection is available. Nor would we expect this person to be able to use it toward a valuable end. Similarly, valuable knowledge is often tacit and does not necessarily transfer cheaply to the level of the explicit (Nonaka, 1994, 21-22; Polanyi, 1958). Attaining a particular set of knowledge may be costly as acquisition often requires practice, memorization, and reformulation of existing knowledge. In our model, we observe opportunity cost entailed by the choice of one set of knowledge over another. If a new set of knowledge is chosen for use, it is employed at the cost of foregoing the set of knowledge that the agent would have used otherwise. Finding this appropriate set of knowledge for accomplishing some end may only be possible by a process of trial and error (Hayek, 1955; Johsnon-Laird, 1980). Learning comes at a cost (Nelson and Winter, 2002, 30).

Learning results from successful adaptation. Humans continually adjust the structure by which they interact with one another. In the world that we observe this includes adaptation of productive strategies and institutions. All of these – strategy, institutions, rules, and so forth -
fall under the broader heading of technology. We observe coordination via persuasion that is ongoing – i.e., agents copy their wealthiest trading partners – and is especially apparent when the system experiences an exogenous disturbance that benefits innovators who successfully develop a strategy that profits from the change (Aldrich and Martinez, 2001)\(^\text{11}\). As Aldrich and Martinez argue, humans exhibit a tendency to innovate and duplicate: “playfulness and experimentation are natural human impulses . . . However, people’s tendency to defer to the beliefs of others blunts the full expression of these impulses.” Thus, entrepreneurship is modeled in terms of strategy adaptation to changes in the environment and replication of strategies that appear to be successful.

The level of entrepreneurial adaptation is a function of demand for such adaptation. As suggested by the discussion of Schumpeterian innovation as a function of the Kirznerian entrepreneur, entrepreneurs “change existing obsolescent societal patterns (of relations, organization, modes of production) to render them more compatible with the changed environment (Etzioni, 1987, 176).” Within our model, this is a change in strategy much as described by Nelson and Winter (1982). Agents in this rendition of Sugarscape develop strategy simply by observing other agents and experimenting by trial and error. Compare this to Zhang (2003) whose innovative agents invest in R&D, but are capable of learning from knowledge spillovers.

Our agents learn by marginally adjusting rules of behavior and judging their results in light of the success of other agents. By this process, the agents collectively overcome ontological uncertainty, which is uncertainty that can be overcome by recognition of logic that appears to

\(^{11}\) In this respect, the authors refer to entrepreneurs as innovators and reproducers.
govern processes of interest. This is distinct from radical uncertainty which is category of uncertainty that includes events that are not categorizable and, therefore, not predictable.

Ontological uncertainty exists for an agent who is yet to identify and adopt a strategy that can help him interpret and reduce the cost of a future events yet assigned no category by the agent:

Sometimes the entity structure of actors’ worlds change so rapidly that the actors cannot generate stable ontological categories valid for the time periods in which the actions they are about to undertake will continue to generate effects. . . The entities of which such propositions would have to be composed are simply not known at the time the propositions would have to be formulated. (Lane and Maxfield, 2005, 10)

If an agent suffers from ontological uncertainty, she can overcome it after the occurrence of the unexpected event. Such events are predictable, at least probabilistically, once this new set of knowledge is acquired. Particular strategies perform the function of predicting the environment and tend to be adjusted when expectations provided by them that are upset. A person who has never experienced an earthquake in a given region may not act in a matter that reflects this risk. Once the event occurs and is recognized, the actor can move to correct the error by copying those who appear to have been prepared. A given strategy may also help agents using it to cope with a future category of event that has not otherwise been recognized by the agent. The categories and procedures provided by a rule set help agents who use them survive. Such a case appears in the presentation of Sugarscape below when agents of a previously unsuccessful class thrive in response to a demand shock.

A Meta-view of Creativity at the Individual and System Levels

Individual creativity undergirds much entrepreneurship. We must be careful in defining creativity. The entrepreneur does not create ex nihilo (Bibow, Lewis, and Runde, 2005). The potential for novelty generation must first be present in the configuration of the system. There is feedback between the creative potential embodied within society and decisions of
entrepreneurs in it. The entrepreneur “must choose from the ‘plurality of rival possibles’”
(Buchanan and Vanberg, 1991, 172 cites Shackle, 1983, 37). The entrepreneur searches a
strategy space. This includes a vast number of contexts in which an entrepreneur may act and
some finite set of strategies that the entrepreneur may choose to employ in each discrete
context.

Felin, et al., (2014) refer to this space of potential for creativity as the adjacent possible:

It is not possible to map all of these possible adjacencies, just as all the uses of a
screwdriver are not algorithmically listable, nor are all opportunities that arise listable or
prestatable. . . Moreover, the unprestatable new use further alters the phase space of
evolution in unprestatable ways, precluding our ability to write laws of motion for that
evolution. (8)

The role of the entrepreneur is to choose action that brings into realization an adjacent possible.
Whether or not by intention, action chosen can lead an entrepreneur to exploit hitherto
unrealized profit potentiated by the system, while simultaneously creating new and removing
other profit opportunities from the choice set. In a similar vein, Foss and Klein argue that
entrepreneurs create profit opportunities in the process of exploiting other opportunities
(2012). Just as the evolutionary development of a swim bladder “constitutes an adjacent
possible empty niche, or ‘opportunity’ altering the future possible evolution of the biosphere”
(Felin, et al., 2014, 7), the invention of petroleum refinement made possible the invention of
internal combustion engines:

It seemed clear to many would-be innovators that such engines could be mounted,
somehow, to wings to create a powered flying machine. Thus, powered heavier-than-air
flight was part of the adjacent possible for the Wright Brothers. (Koppl, et al., 2015, 8)

Koppl, et al., adopt a combinatorial view of creativity. This creativity naturally emerges from the
system:
If the system’s dynamics are ‘creative in our sense, then it constantly generates new elements (and new uses of old elements) that might be combined and recombined in novel ways.

This perspective assumes learning on the part of economic agents. Otherwise, how could these agents develop abstract categories necessary for making full use of these new elements?

Creativity in the heuristic version of Sugarscape is also combinatorial with new categories being provided to via mutation. Despite this limitation in formal modeling, the locus of creativity in the economic system demands a theory of knowledge and learning that takes into account the adjacent possible. As the composition of the population changes, so too does the array of strategies that will promote the survival of a given agent. A strategy that does not work under one context may be enabled by the emergence and practice of new strategies in the model. Likewise, the development of some strategies may disrupt the efficacy of strategies that would work otherwise.

Given the existence of the adjacent possible, a socio-economic system is never actually in equilibrium. Unexploited profit opportunities are always present. Once recognized by entrepreneurs, the persistent state that once dominated is followed by a period of reconfiguration that first disrupts the old persistent state and eventually replaces it with a new, relatively stable configuration. Israel Kirzner discusses this pattern in his attempt to ameliorate the differences between the Schumpeterian and the Kirznerian entrepreneur. For Kirzner:

. . . the essential element in that role [of an entrepreneurial leader] was its potential of impinging on an initial state of disequilibrium, and, through alertly noticing (“discovering”) those errors of which the state consists, moving equilibratively to correct them. (1999, 7)

Given some innovation, the entrepreneur moves to create an instance of it – which in our model exists as a new strategy – and he must do so in light of existing resources and their prices.
Innovation disrupts the old order and promotes a new, more efficient regime of coordination in the market.

Innovation comes not only in the form of instances of technology formed of inanimate matter, such as a screwdriver or computer, but in the form of existing social organization. The development of new social technology is evidenced by a change in the organization of agent interaction. Economists refer to these modes of organization as institutions (North, 1990; Ostrom, 1990). Institutions are coordination devices, shared and interlocking conceptions such as norms and laws that agents internalize to a greater or lesser degree (Denzau and North, 1994; Crawford and Ostrom, 1995; Koppl et al., 2015, 22; Boettke, Coyne, and Leeson, 2008). They are social technology emerge from coalescent mental technologies. Institutions constrain agent action, shaping the array of actions available for an agent so as to promote coordination among diverse agents.\footnote{Leeson, Boettke, and Coyne (2006) provide a useful example of this sort of open-endedness in their discussion of conflict and cooperation.} Agents may also influence institutions by their actions (Kuchař, 2015) and thus bring into realization an adjacent possible. In our model, property rights are stable while the price structure evolves in response to agent interaction with the environment.

The general structure of institutions serve as a model for knowledge transfer and transformation, including the development of strategy. These all fall under the broader heading of technology. Consider the archetypal institution, language, which exhibits precisely these patterns. Concerning the causal force of such an institution, Bibow, Lewis, and Runde note:

\[\ldots\] we would wish to avoid the opposite extreme in which social structure bears so heavily on people that they have no choice at all. \ldots\] Further, while someone in Britain who wishes to communicate is compelled to conform more or less with the rules of English grammar in order to be understood, those rules do not determine what the person says. There also exists the possibility that the creative use of language (via metaphor, say) will lead to the transformation of the rules of governing the use of language. (2005, 522)
Agents coordinate around a stable set of beliefs that we may refer to as rules. Elements that comprise the language are shared to a significant, but not perfect, extent. Allowance for less than perfect coherence allows for coordinating games to evolve over time as changes in agent action promote recoordination (Wittgenstein 1953; Hayek 1967; Koppl et al., 2015). This leaves open the possibility for adaptation to changing context as successful agents innovate in a manner that is persuasive to others. Even when successful strategies are not persuasive, if they survive the competitive process their rationality is legitimized and can be integrated into the economic system (Alchian 1950; Kirzner 1962; 1963b; Becker 1962; 1963).

**Creativity in Sugarscape**

Choice plays a role in the trajectory of the economy. The individual chooses actions according to rules he has adopted. In other cases, the agent may choose a new rule and, in the process of generating new categories to guide action, act as innovator. Within the model, the ability to choose new rules is enabled by a positive rate of mutation. Action by an agent represents a change to the environment, whether that action results from the choice to continue submitting to an old rule structure or to change the set of rules that the agent uses to interpret the environment. Choice in terms of changing rules is modeled much as biological mutation is modeled in an agent-based model of evolution (Sims, 1994). The population of agents in an agent-based model choose from the space of rules and parameters provided by the model builder. These options represent their adjacent possible. The space of the adjacent possible, and therefore the scope of creative potential, is finite in any agent-based model.

Despite this limitation, agent-based models represent an opportunity to observe the development of creativity. This includes Schumpeterian disruption and the generation of a new
persistent state that results from innovation. The very entrepreneur whose innovation is disruptive, so long as he is fulfilling a niche, works to move the system to an improved regime of coordination. The model simulates disruption that is the result of a positive demand shock. Unlike the Schumpeterian disruption, which represents a positive supply shock, this disruption does not bring with it an obvious positive benefits. This negative pressure often promotes combinatorial creativity as combinations of known strategies and parameter values prove useful for recoordinating activity under the new conditions.

Creativity is bound by the space of parameters and strategies made available to the agent. I have discussed in greater detail the operation of this heuristic model of Sugarscape elsewhere (Chapter 1). For our discussion, I will provide only an essential description of the model. Agents can choose from among 8 possible combinations of agent strategies (Table 1.1). These represent different classes of agents. Each strategy has associated with it parameters that may take on some limited range of values. An agent’s choice of strategy and parameter values affects his expected levels of profit, and therefore, his fitness.
Agent Goals

Agents consume two resources, sugar and water, each at a given rate. If an agent is unable to acquire enough sugar or water such that the level of both remain above zero, the agent is removed from the population, much as a firm that declares bankruptcy withdraws from the marketplace.

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\(^{13}\)Basic Only: Black; Basic Herder: Grey; Basic Arbitrageur: Red; Basic Herder Arbitrageur: Orange; Switcher Only: Brown; Switcher Herder: Yellow; Switcher Arbitrageur: Dark Green; Switcher Herder Arbitrageur: Light Green
Classes

Agent strategies are divided into main classes and subclasses. An agent must choose 1 of 2 main classes: Basic or Switcher. Each period, Basic agents move to the area with the highest valued resource within their field of vision, regardless of whether that resource is sugar or water. Switcher agents seek to acquire a particular type of good in a given period. They move back and forth between the field of sugar and of water at some rate, ultimately choosing to move to the area with the highest valued resource that they prefer.

Either main class may be augmented by one or both of the available subclasses: Herders and Arbitrageurs. Herder agents copy the traits of their richest trading partner upon meeting them. Arbitrageurs keep track of past prices and compare the average to a price they believe represents the true value of each good. This price is chosen randomly when the agent is first instantiated. Each of the 8 particular instantiations of a class is represented by a different color.

Exchange

Agents exchange with their neighbors. Sugar and water are traded directly. To decide how much to exchange and at what price, agents consider their target reserve levels. These levels are chosen randomly at the beginning of the agent’s life from a distribution defined by equation 2.1 and shown in figure 1 (bin size = 20):

\[ 1 \leq R \leq \left( \sqrt{R_{\text{max}}} \right)^2 \]

*Equation (2.1)*

Where:

\[ R = \text{Target Reserve Level} \]
\[ R_{\text{max}} = \text{Maximum Target Reserve Level} \]
Prices are denominated in sugar, which is the inverse of the price of water. If an agent has less of a good than is stipulated by his target reserve level, he will raise the price he is willing to pay. If he has more than the target reserve level, he will lower the price. The magnitude of the price change increases with the size of the discrepancy between desired holdings and actual holdings. This is generalized for either good according to Equation 1.1.

In addition to changing the bid-price and ask-price, which are the same for a single agent, agents can also adjust target reserve levels. This is different than in chapter 1 where agents only adjust price. Agents adjust target reserve levels when their level of wealth changes. This is sensed by the agent if holdings of each good are either both above or both below the agent’s target levels. In the case that he has excess of each, the agent will raise each target level. In the case that each target level is higher than actual holdings, he will lower each target level:

$$T_{g,t} = T_{g,t-1} \times (1.01)^{\delta}$$

*Equation (2.2)*
Where:
\[ \delta = \begin{cases} 
1 & \text{if } q_{g,t} > T_{g,t-1} \\
-1 & \text{if } q_{g,t} < T_{g,t-1} 
\end{cases} \]

When two agents meet and each has excess of different goods from one another and less than the desired quantity of the other good and if each agent’s bid price for their desired good is higher than the other’s ask price of that good, exchange will occur according to a price randomly selected in the range between the bid and ask prices (Equation 1.2).

**Mutation**

The model represents creativity in terms of a mutation rate. Unlike in chapter 1 where the mutation rate governing agent creativity is the same between all agents, agents are assigned a mutation rate between 0 and a given maximum value. For the visualizations shown below, the maximum value chosen is 0.25. This means that the agents have at most a 25% chance of changing each parameter or strategy component. When agents reproduce, the offspring inherits this mutation rate. The mutation rate itself may also mutate at rates in accordance with that rate. For an agent with a mutation rate of 0.05 there is a 5 % chance that a new agent produced by him will be assigned a new mutation rate between 0 and 0.25. The average rate of mutation across the population tends to fall over time so long as the system does not experience an external shock or enter a configuration that is suboptimal compared to a former configuration.

**Results**

Results are drawn from two experiments. In Experiment 1 sugar and water consumption rates are adjusted from 0.3 to 0.7 units per tick, using intervals of 0.01. Each parameter combination is tested using 100 different trials. In Experiment 2, sugar and water consumption rates are tested from 0.25 to 0.65 units per tick. Each parameter combination is tested 10 times.

*Innovation and Schumpeterian and Kirznerian Entrepreneurship in Sugarscape*
It is not possible to rank the efficiency of strategies without context. Results suggest, however, that Basic agents who have no augmentation from the Herder and Arbitrageur classes are always the least efficient class of producers. When a new strategy is introduced to the economy, these agents are quickly replaced. The new classes of agents that take their place tend to raise productivity. Throughout the process, disruption from innovation has positive effects as measured by the population levels which indicates, by definition, the total level of production (Figure 2.9).\(^{14}\)

The population dynamics reveal a series of transformations from a given configuration to an adjacent possible. Every run begins with the same pattern. The number of Basic agents continues to grow until competing strategies show their superiority and are thereafter reproduced. By the time the model progresses to period 1500, most Basic agents have not survived (Figure 2.3).\(^{15}\) By this point, Arbitrageur agents have replaced these agents as they profit from tremendous price volatility common in the early stage of a trial (Figure 2.6). The substantial increase in population of Arbitrageur agents in the first 1500 periods sets the stage for the emergence of a new economic configuration dominated by Switcher agents. Innovation destroys the early configuration dominated by the presence of Basic and Arbitrageur agents with a strategy that is more efficient given the higher population level. They engage in Schumpeterian innovation (Schumpeter, 1912), disrupting the old order temporarily and bringing the system to a new equilibrium in a manner described by Kirzner (1999). This occurs endogenously.

\(^{14}\) Surviving agents must produce at least as much as they consume.
\(^{15}\) This and all other heatmaps presented below represent average values at each period runs across the parameter space. (Caton 2017)
Switcher agents, including instances augmented by the Herder class, more efficiently fill the niche that had been held by Basic agents (Figures 2.3-2.5). Changes in the composition of surviving agents can be explained in light of wealth per capita of each group, a proxy for the average rate of return, for each agent class. Early on, Basic agents who have survived the initial disequilibrium perform well, holding, on average, enough resources to about period 1000 (Figure 2.7). They are soon replaced by Switcher agents whose relatively high level of per capita wealth indicate that they have discovered a strategy that earns them above-normal rates of profit (Figure 2.8). Their rates soon become the normal rates of return. This allows them to expand their industry as these agents have sufficient resources to reproduce and are also replicated.

![Figure 2.3. Basic Class as Percent of Population – Experiment 1](image)
Figure 2.4. Switcher Class as Percent of Population – Experiment 1

Figure 2.5. Herder Class as Percent of Population – Experiment 1

Figure 2.6. Arbitrageur Class as Percent of Population – Experiment 1
Figure 2.7. Basic Wealth Per Capita – Experiment 1

Figure 2.8. Switcher Wealth Per Capita – Experiment 1

Figure 2.9. Population – Experiment 1
**Positive Demand Shock**

At period 10000, the model experiences a positive demand shock with the doubling of the sugar consumption rate. This is a doubling of demand for sugar.\(^{16}\) This change in circumstances represents a change in the payoffs of each strategy. The economy has been thrown from its former equilibrium-like, persistent state and requires a change in strategies from those previously used in the game of production. Agents must search the strategy and parameter space to find the profit opportunities generated by this disruption. In some cases, the level of adjustment required to move to a sustainable configuration is substantial while in others it is less.

The level of change required is reflected by the increase in creativity across the system. The average and median mutation rates increase after the demand shock throughout a significant portion of the parameter space (Figures 2.16-2.18). Crisis in the system demands creativity from the population of agents. Our agents are naïve in this sense that they are not told directly that there has been a demand shock. None of them receive a command from the program telling them to increase creativity. Rather, those agents that are less creative after the shock tend to survive at a lower rate than those agents who are endowed with higher than average levels of creativity. Solely through a change in the payoff structure does the system itself regulate the level of creativity present.

**Herding and the Spread of Useful Knowledge**

Agents are themselves part of the environment. Therefore, a change in agent preferences, which include a change in an agent’s needs for survival or a change in beliefs and

\(^{16}\) We could have generated a similar result by cutting the flow of sugar supply in half.
strategies, influence the array of incumbent future states manifested by the environment. The passage of time matters.

The evolving mixture of agent types in a population at different times and under different conditions reveals the nature of knowledge dispersion and a need for creativity. The changes in the proportion of Herder agents in different parts of the parameter space before and after the shock reflect the need for the spread and creation of new knowledge. One peculiar feature stands out. Regions of the parameter space where Herder agents are a significant portion of the population in the first part of the experiment are regions where they are not as substantial in the second part (Figures 2.12 and 2.13). These tend to be the regions where the initial consumption rate for each good exhibit greater disparity. Likewise, in regions where Herder agents were relatively less present in the first part of the experiment, they comprise a greater proportion of the population in the second. These are regions where initial consumptions rates are equal and, therefore, Switcher agents perform well before the demand shock.

When system is shocked by a doubling of the sugar consumption rate the experiments where Herder agents have already done much of the work of sharing successful strategies and parameter values, agents have a more useful set of knowledge to draw from and adapt than those who have been primarily dependent on a Switching strategy under less extreme conditions. Higher levels of sharing leads to a relatively lower need for sharing after a shock and vice versa.

**Levels of Creativity**

Just as there occurs elevated levels of Herding in regions of the parameter space where the Switching strategy is relatively less efficient before the shock, those same regions exhibit
higher levels of creativity as well. Both before and after the shock, average mutation rates are higher in regions where the proportion of Switche agents is lower. In these regions, prices must guide production to a greater extent as a constant rate of switching back and forth is insufficient for meeting the consumption requirements of agents.

Arbitrageurs are agents who intentionally respond to changes in observed prices. They choose to produce a good so long as the average price of sugar remains above or below the price they believe is the level appropriate for changing their target good. This allows arbitrageurs to consistently target the good that is relatively scarce. When price variance is higher, the profits to be gained by Arbitrageur agents is also higher. The demand shock appears to shift the distribution of Arbitrageurs to the left on the heatmap (Figure 2.14 and 2.15). A comparison of heatmaps showing the percent of the population that is composed of Arbitrageur and Switche (Figure 2.10, 2.11, 2.14, 2.15) agents with heatmaps showing mutate rates (Figures 2.18 and 2.19) suggest that difficulties that arise for a population composed primarily of Switche as consumption rates diverge. This requires a more intense search of the parameter space by competing agents. Entrepreneurs must adapt continually to the landscape, including to one another.

More generally, there is a tendency for mutation rates to increase after the shock. While this tendency is not universal, it appears over much of the behavior space. If the given mix of strategies and parameter values is insufficient for adaptation, agents must discover new values. This should come as no surprise. In times of crisis, whether for a person, a firm, or a government, it is common for actors to adapt known strategies or to implement strategies that have been untried. After a short while, the revenue derived by a strategy reflect its value.
Figure 2.10. Switcher Class as Percent of Population – Period 15000 – Experiment 2

Figure 2.11. Switcher Class as Percent of Population – Period 25000 – Experiment 2

Figure 2.12. Herder Class as Percent of Population – Period 15000 – Experiment 2
Figure 2.13. Herder Class as Percent of Population – Period 25000 – Experiment 2

Figure 2.14. Switcher Class as Percent of Population – Period 15000 – Experiment 2

Figure 2.15. Switcher Class as Percent of Population – Period 25000 – Experiment 2
Shocks Promote Efficiency in the Price Structure

In its early state, the Sugarscape economy experiences a significant degree of price coordination. Unlike in the standard economic theory, prices are set in decentralized fashion similar to Axtell (2005) and Epstein and Axtell (1996) and without neoclassical utility functions as in Gode and Sunder (1993). Agent valuations of goods early on do not systematically match their own consumption rates. As a result, convergence toward particular level of prices takes longer than in Axtell (2005) and Epstein and Axtell (1996) as the means to convergence is a process of trial and error.

Price variance is high before as compared to after the shock. The increase in variance is negatively correlated with distances between the consumption rate for each good. Agents seem to get along just fine with a wide spread of prices in certain regions before the shock. Early in the run, arbitrageurs move in to offset this price variance. In regions where the consumption rate of water is high relative to that of sugar, the arbitrageur strategy appears to be less efficient in profiting from the imbalance.

Price variance tends to fall after the positive demand shock, though it does not always fall. In the cases where price variance increases after the shock, these increases tend to be limited compared to the highest levels of price variance observed in some runs before the shock. The population initially manifests an orientation which reduces price variance, but in many cases still leaves it relatively elevated. In these cases, given preferences and knowledge make greater reduction an inefficient outcome. The negative shock demands efficiency increases from the population. As price variance increases, arbitrageurs find it profitable to allocate. These agents grow wealthier after the shock. It appears that the population has the knowledge necessary to embody such a configuration once the array of costs is affected by the
positive demand shock. While there are some cases where price variance increases after the shock, the maximum height of price variance across the parameter space is reduced after the shock.

**Multiple Rates of Return**

Unlike the results from chapter 1, there does not appear to be a single level of wealth per capita shared between classes. Rather, there appears to be two levels that emerge. This is likely an effect of allowing agents to adjust reserve levels upward and downward, which they are not able to do in the set of experiments from chapter 1. This has reduced the profits of Arbitrageur agents such that they tend to be outcompeted in many circumstances, though it is not uncommon for them to find a niche. When they do comprise a substantial portion of the population, the average rate of return is often lower than that of Switcher and Herder agents and tends to match that of Basic agents. Classes seem to converge to two levels, one comprised of Switchers and Herder agents, the other comprised of Basic and Arbitrageur agents. As the returns of these latter classes tend to be transient, they are not clearly captured in heatmaps. They can be observed in individual runs (Figures 2.25, 2.26).

At times, the average returns of Basic and Arbitrageur agents can be higher than that of Switcher and Herder agents (Figure 2.25). This suggests that convergence to different observed levels of returns may be a function of variance of returns and risk. This explanation is consistent with the observation that, under some circumstances, returns for all classes converge to a single level (Figure 2.26). These cases are rare. The presence of Basic and Arbitrageur agents maintains knowledge of strategies that are stabilizing to the system during times of need, though these agents often bear the costs of such provision.
Figure 2.16. Average Mutate Rate – Experiment 1

Figure 2.17. Median Mutate Rate – Experiment 1

Figure 2.18. Average Mutate Rate – Period 15000 – Experiment 2
Figure 2.19. Average Mutate Rate – Period 25000 – Experiment 2

Figure 2.20. Switcher Wealth Per Capita – Period 15000 – Experiment 2

Figure 2.21. Switcher Wealth Per Capita – Period 25000 – Experiment 2
Figure 2.22. Herder Wealth Per Capita – Period 25000 – Experiment 2

Figure 2.23. Herder Wealth Per Capita – Period 25000 – Experiment 2
Sugar Metabolism Scalar = 0.35 Water Metabolism Scalar = 0.5
Run 5 of 100

Figure 2.24. Class Composition – Trial from Experiment 1
Figure 2.25. Wealth Per Capita by Class – Trial from Experiment 1
Sugar Metabolism Scalar = 0.35 Water Metabolism Scalar = 0.5
Run 5 of 100

Figure 2.26. Wealth Per Capita by Class – Trial from Experiment 1
Sugar Metabolism Scalar = 0.37 Water Metabolism Scalar = 0.5
Run 5 of 100
Figure 2.27. Mean Prices – Run from Experiment 1

Figure 2.28. Price Variance – Experiment 2 – Period 15000

Figure 2.29. Price Variance – Experiment 2 – Period 25000
Implications

In chapter 1 I have shown that the inclusion of knowledge that is structured allows economists to investigate strategy and its relationship to search costs. A fundamental principle of market order, the law of one price, is maintained within this paradigm. This work extends that project, showing the relationship between coordination and creativity. It extends the conversation concerning distinctions and similarities between the Schumpeterian and Kirznerian entrepreneur. Both seek to earn profit and, in the process, move the economy to an equilibrium present in a discrete adjacent possible. The Schumpeterian entrepreneur brings new categories of means and ends to the social-economy in the process of innovation while the Kirznerian entrepreneur persists in application of this new, useful knowledge until the economy has fully entered a new, equilibrium-like persistent state.

Innovation in the model occurs as changes and augmentations to strategy, rather than innovation that manifests in new combinations of physical capital. Both can be described under the more general terms of technology. Our Schumpeterian innovators in the model produce cost reducing technology that manifests in the form of human capital as these new strategies are executed. If we are to better understand the process of economic change, it is necessary to view technology in terms of logic, its evolution, and its manifestation in an environment. Technology can be conceived of as blueprint of action and organization that evolves over time.

I have also shown that some strategies may fill transient niches that earn below market rate of returns on average. These have an obvious corollary of a world with multiple equilibria, however they are not long-run phenomena as these niches disappear and reappear. The agents that earn these lower returns outcompete some agents from classes that tend to earn higher
rates of return so long as they are able to correct the imbalance not reduced by those wealthier classes.

This work also shows that prices are only one means of coordination. They represent a language-game (Kripke, 1982; Bloor, 1997; Koppl, 2002) by which agents coordinate around a regime of property rights and engage in voluntary exchanges with their property. Entangled in the pricing game are, for example, imitation games and, outside the context of this model, political games (Bikchandani, Hirshleifer, and Welch, 1998; Earl, Peng, and Potts, 2007; Asch, 1955; Bibow, Lewis, and Runde, 2005; Dekker, 2016; Wagner, 2016). A challenge to be confronted by the social scientist in the modern era is to understand not only how these games function in isolation, but also how they interact with one another during social intercourse. I hope that this work has shown how agent-based modeling in combination with substantial methodological and epistemological foundations can contribute to this conversation.
Citations


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An Evolutionary Theory of Knowledge: Knowledge’s Structure, Generation, Transmission and Significance to Social Theory

A Brief Sketch of Knowledge

The object of social theory is society as defined by its human agents and their interactions with one another and the environment. Any orderly interaction requires some set of knowledge that coordinates agent action with the features of the environment in which the agent acts and some mechanism that updates that knowledge. Though human cognition is affected by biological structure that has resulted from evolutionary processes, humans do not, a priori, have a fully developed base of knowledge that allows them to interact with the environment. They must develop such knowledge by interaction with the environment, which includes interaction with other humans. This knowledge and the process of learning by which it develops is typically taken for granted within economic theory (Hayek 1937). In what follows, I introduce a sketch of knowledge and learning whose elements will be further elaborated.

Reality is perceived through the senses. The data perceived by them is organized in accordance with prior beliefs, those statements concerning reality that one assumes as fact. As Kant (1998) observed:

Even among our experiences cognitions are mixed in that they must have their origin a priori and that perhaps serve only to establish connection among our representations of the senses. . . they make one able to say more about the objects that appear to the senses than mere experience would teach, or at least make one believe that one can say this, and make assertions contain[ing] true universality and strict necessity, the likes of which merely empirical cognition can never afford. (128)

If data is lacking, one’s theory of the observed phenomena fills in the details. If there is
discrepancy between one’s beliefs and one’s observation of reality, beliefs must be updated so as to facilitate new data. If the belief that appears to be violated is a core belief, the observer may investigate further to reveal the nuance that led to the apparent violation.

Such updating is a definitive element of agent learning. As part of the learning process, individuals attempt to copy the actions of others and the logic that drives those actions. They test predictions generated by this knowledge – i.e., their beliefs – against reality. Describing a process of learning, which is really the process of the generation and refinement of knowledge, requires a nested perspective. Learning occurs at different levels. At the most basic level, learning occurs within the body of the agent. Internal systems adjust according to input that is derived from external conditions (Hayek 1952a; Clark 2016). The interaction of these systems and the environment generate what we experience as consciousness (Dennett 1991). The consciousness generated operates in terms of categories (Searle 2006; Mises 2007). Agents hold that these abstract categories of objects are related causally to one another. What results is a mental model representing agent knowledge. The knowledge generated can be explicit, where the agent is conscious of the relationship assumed, or tacit, where the agent interacts with the objects without having explicitly identified the relationship that he implicitly assumes by his interaction with the environment (Polanyi 1958; Nelson and Winter 1982, 76-82). By speech and by action more generally agents communicate their understanding to one another. If the interaction of agents is to be rich and constructive, interpretation of language by agents – I use the word “language” to denote meaning both in words and in actions – must be common (Wittgenstein 1953). For this reason, learning tends to occur within a community where repeated interaction supports the development of shared language and concepts (Polanyi 1958, 207-9).
Learning occurs in groups. In this spirit, we see divisions in schools of thought in academia and the emergence of sects within religions. Division at the macroscale represents cohesion within the groups where common identity and language creates a notion of distinction between groups and a space of privacy within them. To the extent that groups have a means of communicating with one another, agents in these groups might also learn from one another. Divisions may result, not only due to disagreements within a given framework of understanding where foundational assumptions are shared, but heterogeneously interpreted. Differences in belief concerning foundational claims may have radical effects on the interpretation of phenomena, including the tradition in contention. Despite this, subgroups that are at odds over interpretation within a tradition often share many practices and beliefs. Consider that we see a division within Islam concerning the legitimacy of the claim of either the Sunni or the Shia over inheritance of the legacy of the prophet Muhammed (Armstrong 2000; Denny 1994), yet we also consider the totality of Islam to represent a body of thought. Such bodies of thought include claims about objective circumstances as well as normative claims that are commonly implied by its assumptions. Common understanding of agents within a group provide the foundations for institutionally guided interaction. Institutions are coordination devices, which include norms, rules, and strategies, as well as formal institutions that explicitly denote a hierarchy of offices, each subject to particular rights and obligations (Ostrom 1986; 1990; Searle 2005).

Finally, knowledge is generated and acted upon in environments where resources are scarce. If a set of knowledge does not help an agent or group of agents survive in a given environment, agents employing that set of knowledge will, on average, not survive. Ideas, just like organisms, must adapt to the environment or else face lower rates of survival or extinction.

Explanatory Social Theory
The purpose of this explication of knowledge is twofold. First, a pure social theory requires coherence with its object of analysis: society (Wagner 2010; 2016). Society is comprised of individuals and is defined and continually transformed by the actions of these agents. As psychologist Carl Jung observed, the individual is “the instigator, inventor, and vehicle of all these developments, the originator of all judgments and decisions and the planner of the future (1957, 45).” In economics, we refer to such an actor as an entrepreneur (Kirzner 1973; 1997; Rizzo and O’driscoll 1985; Koppl 2002). The action of the individual is coterminous with logic. It is agent understanding of the environment that drives her interaction with it (Mises 2007; Johnson-Laird 1980). This understanding may be implicit or explicit. The entrepreneur employs some given means to attain desired end, or more generally, to bring about some end state that she prefers to the state that would arise absent her intervention (Sarasvathy 2001). The end attained is a final good, while objects produces to serve as means for such attainment are intermediate goods (Menger 1871). If I build a net to catch more fish, the net is an intermediate good that serves as means to catch fish, which are final goods.

In describing the nature of a good, Carl Menger identifies agent understanding as necessary for the object’s categorization as a good. In order for an artifact to be a good entails four requirements:

1. A human need
2. Such properties as render the thing capable of being brought into a causal connection with the satisfaction of this need.
3. Human knowledge of this causal connection
4. Command of the thing sufficient to direct it to the satisfaction of the need. (1871, 52)

We concern ourselves here with the second and third properties. Traditional analysis represents these second and third properties in a manner that lacks dimension. Most theorists have been
ignoring the texture of agent knowledge.\textsuperscript{17}

The second purpose descends from the first. If we are to formally model society, meaning that we model human action as guided by agent logic, we require identification the logic described as “a causal connection”. Any explanatory theory can be described as a theory whose ontology is an abstraction of the agents, artifacts, relationships, and transformational processes present in the real world (Fleetwood 2015). Theoretical objects and processes must correspond to objects and processes in reality.

A robust social theory requires consideration of different levels of analysis. We have first to consider the logic of the human agent. It is action generated by agent intention that determines the ends toward which this logic is ultimately employed (Searle 1979). This action is affected, as well as interpreted, by other humans as they comprise part of the environment with which any social agent interacts. Agent interaction drives the formation of institutions. These represent shared knowledge that allow agents to communicate and, therefore, interact with one another in orderly fashion. They imply that a finely detailed social theory requires identification of the internal states that drive agent action as well as mechanisms that coordinate beliefs and, thus, actions between agents. What follows will provide a general structure of knowledge and elaborate on the role it plays in any social theory.

**Rationality: Individual and Collective**

**Agent Learning and Cognitive Structure**

Humans act. Human rationality drives that action (Menger 1871). Rationality is not, as implied within some systems of economic thought, utility maximization where preferences are

\textsuperscript{17} Notable exceptions include Arrow (1974), Williamson (1973), Simon (1974), Hayek (1937), Aumann (1976), Ostrom (1990), among others.
reflected by a utility vector whose units are homogeneous (Debreu 1959; Arrow and Hahn 1971). Human agents act with intention to realize ends they most value. They attempt to maximize utility *ex ante*, however, this attempt is not the same as an accomplishment of the task. Utility maximization, whether local or global, is an outcome that occurs *ex post*, arising from a process of trial and error within an environment subject to competition and selection (Alchian 1950). This process yields a result typically assumed by neoclassical theory. It tends to bring agent expectations – agent knowledge – into convergence such that they match the objective reality, which includes the expectations of other agents.\(^\text{18}\)

Human agents learn by two modes. The originary mode of learning, that which identifies and exploits hitherto unperceived opportunities within the system, is a process of trial and error. The result of action is interpreted by observing agents. Agents who are better than others at predicting the future in an environment that constantly generates novelty, and therefore are better at accomplishing goals within it, tend to be those agents who lead by example (Dekker 2016; Henrich and Gil-White 2001). Other agents who recognize the value of an exemplar agent’s strategy will attempt to adopt the exemplar’s strategy. Most learning occurs by a process of copying the strategies of others and applying them within one’s own context (Bikhchandani, Hirshleifer, and Welch 1998; Earl, Peng, and Potts 2007; Hayek 1967).

\(^{18}\) This is in accord with two points raised by Hayek (1937) concerning social theory that proposes convergence of agent expectations:

... in order that all these plans can be carried out, it is necessary for them to be based on the expectation of the same set of external events... The plans of different individuals must in a special sense be compatible if it is to be even conceivable that they will be able to carry all of them out. Or, to put the same thing in different words, since some of the 'data' on which any one person will base his plans will be the expectations that other people will act in a particular way, it is essential for the compatibility of the different plans that the plans of one contain exactly those actions which form the data for the plans of the other. (37, 38)
To formally model the agent, we move beyond general references to learning and identify in abstract the primary elements involved in this process. Ego consciousness is the thinking, observing part of the agent that affirmatively states “I am”. It abstractly represents the reality of the human agent. Some parts of one’s understanding, such as habits, do not lie within the purview of agent consciousness (Dewey 1906). Knowledge is also embedded in action and processes that lie below the awareness of consciousness. Both knowledge contained in action and in conscious abstraction can be represented ontologically: represented in terms of objects, relationships between those objects, and processes that transform both of these (Lawson 2014; Menger 1963, 37). Explicit denotation of the agent’s mental model includes both explicit and tacit knowledge.

An agent’s personal ontology – his knowledge – is the same as his beliefs about the world (Nonaka 1994). It is by these beliefs that the agent will interact with his reality. We can

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19 Dewey attempted to distinguish his theory from the Aristotelian logic, but this distinction seems to be self imposed. Dewey’s use of evolutionary mechanisms to his system can be more properly thought of as an extension of Aristotelian logic rather than as opposition.

20 While Menger does not employ the word “ontology”, he does identify the components of ontology and the role of theory as describing the world as it is:

... and in the field of economy, also, we will thus have to differentiate on the one hand between individual (concrete) phenomena and their individual (concrete) relationships in time and space, and on the other between types (empirical forms) and their typical relationships (laws in the broadest sense of the world). (37)

We have gained cognition of a phenomenon when we have attained a mental image of it. We understand it when we have recognized the reason for its existence and for its characteristic quality (the reason for its being and for its being as it is). (43)

21 Nonaka provides a definition of knowledge as process:

It should be noted, however, that while the arguments of traditional epistemology focus on ‘truthfulness’ as the essential attribute of knowledge, for present purposes it is important to consider knowledge as a personal ‘belief,’ and emphasize the importance of the ‘justification’ of knowledge. This difference introduces another critical distinction between the view of knowledge of traditional epistemology and that of the theory of knowledge creation. While the
conceptualize the personal ontology of an agent by the statement, “X counts as Y in C”. For example, the raising of hair on one’s neck, X, after receiving some strange or unexpected packet of information from a source C, may lead an agent to feel she is in danger, Y (Searle 2006). The agent endows the present scenario with particular meaning and takes action that she believes is appropriate given this integration of information into her knowledge. The same pattern of perception occurs with visual observation of a process. The physical reaction itself represents the most elementary form of interpretation upon which the agent may consciously elaborate (Hayek 1952a; Lewis 2016).

The agent’s environment typically includes other agents. As these agents are also operating with some representation of reality, there must exist some means of coordinating action between them to reduce the incidence of one plan obstructing another. Consider that I chose to drive on the right side of the street today because that is custom in the U.S. (It is also law, but I expect that driver behavior in the U.S. would change little if the law was reduced to a simple norm.) There exists a belief in the mind of each driver that others will follow suit. This common belief represents an institution that coordinates the agents who act in decentralized fashion. Institutions represent common belief among agents about these objects and processes.

An agent’s personal ontology includes only those objects known to the agent and thought to be pertinent to the task at hand. Consider some essential beliefs of a student in primary school. If the student is told that he must write an essay at the desk, the student must envision several things. First he must imagine what the arrangement of the desk will look like.

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former naturally emphasizes the absolute, static, and nonhuman nature of knowledge, typically expressed in propositional forms in formal logic, the latter sees knowledge as a dynamic human process of justifying personal beliefs as part of an aspiration for the ‘truth.’ (15)
He will sit in a chair at the desk and use a pencil to write on the paper. Thus, he links these objects in a cluster, understanding them by their functions and relationships. The desk will serve as a solid base on which rests the paper. He takes his ideas and uses the pencil to transform the paper from a blank sheet into a coherent (ideally) essay. If the student had no concept of what a desk or piece of paper or a pencil is, he would be unable to complete the task. The student will likely not concern himself with the texture of the ceiling or the color of the floor in accomplishing this task as, excepting special circumstances, they lie outside of the domain of the task at hand. Whatever student’s action, the observer can derive at least some of the elements of that student’s understanding from it (Koppl & Whitman, 2004).

The human mind tends to represent an environment in relatively simple terms. Humans can manage only a small number of chunks (objects), 5 to 7, within short term memory (Simon, 1974). Objects (chunks) may be simple or may exhibit complex, nested structure (Miller, 1955). These require experience that generates representations of these objects in the long-term memory. By holding objects of greater complexity in one’s long-term memory, an individual is able to perform more complex operations using short term memory as long-term memory is capable of holding many more objects than short term memory (Miller, 1955; Ericsson & Kintsch, 1995). It stores these objects within a structure of objects, which is itself a macro-object. This sort of nesting greatly increases the ability of an individual to perform complex tasks. It is this function that allows experts, such as chess masters, to greatly outperform novices (Chase & Simon, 1973). Not everyone can be an expert, and no expert has a monopoly on knowledge. Due to computational limitation, knowledge must be distributed.

**Defining Agent Rationality**

Rationality includes two components. The first is described above as an agent’s mental
model or personal ontology. This personal ontology represents some logical structure that relates objects in an environment by rules governing their interactions. For example, if the student in the above example press the pencil to paper and drags it, he likely expects that a dark line will be left wherever the pencil is pressed. The second component of rationality is classification. Agents not only need to understand their reality; they must also order ends. A classifier is responsible for this process (Booker, Goldberg, & Holland, 1989; Holland, 1992).

Systems of artificial intelligence rate decisions according to a formula that scores strategies and the desirability of objects of analysis. Human agents rate decisions according to similar rules that they adopt to govern behavior (Gigerenzer & Goldstein, 1996). An individual who is choosing players for a pickup basketball team (let’s assume these players have not met before), for example, may always choose the player from the group who is the tallest. Such an indicator may help that individual overcome his ignorance concerning each particular player. For ultimate (higher level) ends, the role of selection is taken on by passions, those drivers of sentiment that shade our interpretation of the external world and from which desire manifests (Polanyi, 1958; Hume, 1896; Carroll, 1895; Blackburn, 1995). Free will lies in the choice of man to govern his passions, or not.

We arrive at a more robust formulation of rationality within economics. Some economists assume that agents act in a manner that they expect will maximize utility (Stigler & Becker, 1977; Becker, 1998). All action is presumed efficient given some set of knowledge. While true, this tautology tells us little concerning how agents can adjust their plans in order to promote coordination at the system level (Hayek, 1976; Klein, 2012). 22 Within the static

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22 Klein refers to this as concatenate coordination. An appropriate interpretation of “concatenate” as a verb is “to join”.
framework, agents cannot learn. They respond to incentives, adjusting their ownership of assets according to income and relative prices changes. I present a dynamic framework that allows agent knowledge to change as they *discover* new strategies and learn from agents they perceive to be superior. This allows for a robust formal description of entrepreneurship (Caton, 2017).

We can also identify a relationship between knowledge, preferences, and action. Knowledge represents an agent’s *understanding* of the environment. It is from this knowledge that agent preferences emerge. In contrast to the assertion of Stigler and Becker (1977) who hold that, within an economic model, agent action must be the result of a change in the environment, not preferences, a dynamic model of society does not hold agent preferences constant. Even if they were constant, they are complex as instances of preference ordering is context dependent for a given preference function (Emmett, 2006). A change in knowledge will likely change the preference function of an agent.

There are two modes by which agent actions may adjust absent a change in the environment. In one circumstance, the agent preference changes due to a change in the mechanism that selects ends. The modeler can represent this by a change in a classifier. In reality, these changes are driven by a change in the degree of one’s passion for an object or a change in the object of one’s passion. Preferences depend also on available knowledge. Integration of new knowledge will drive changes in the agents’ patterns of action.

**Language Games: The Structure of Communication and Coordination**

Within the tradition of Arrow-Hahn-Debreu, agent preferences are assumed to be independent of one another. There is no communication between agents except for perceived changes in prices. In this understanding of the economic agent and the society he helps comprise, there is no endogenous dynamic that can arise due to the creation of a disequilibrium
condition for some agents by actions of another (Axtell, 2005). There is also no learning in the sense that agent knowledge changes endogenously. A robust social theory compatible with modern techniques of simulation must accommodate these features.

The static framework requires exogenous shocks to move a system out of equilibrium. A change in variable $x$ leads to some magnitude of change or mean of a distribution of changes in variable $y$. The processes that generate particular relationships between variables that arise through social intercourse are more roundabout. The application of the scientific method to economics strips away the subjectivity and complexity inherent in Human Action. It assumes away the effect of agent perception on social outcomes (Hayek, 1952b).

One way to integrate endogenous dynamics typically absent from theory is for the modeler to provide general scaffolding of action that is defined by some set of rules that govern behavior. For example, agents may respond to changes in the availability of a resource by incrementally adjusting the prices they are willing to pay for a unit of the good. Or maybe an agent has a rule where he responds to the relationship between the actual price of a good and the price that he believes to be the true price. Rules such as these and the parameter values that comprise them guide the interaction of agents.  They can be mixed and matched by the agent in an attempt to improve his or her position. The number of possible combinations are finite yet vast. The number of combinations is too large to be fully identified by any individual. Further, the injection of novelty may allow rules governing action to evolve.

We approach this form of agent interaction and learning abstractly as part of a language game (Wittgenstein, 1953; Kripke, 1982; Lyotard, 1984; Hassard, 1994; Mauws & Phillips 1995;  

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23 In many cases, parameter values are random or change depending on the environment.

24 On application of rules, see Bloor (1997, 10).
A language game is “a set of rules governing action and reaction” and guiding interpretation of action between different players (Koppl & Langlois 2001, 287). If a teacher walks into a room and says, “Let’s begin!”, the appropriate response of the students is to cease conversing and direct their attention to the teacher. The phrase spoken by the teacher under a particular circumstance evokes a response from the students. The response of the students is akin to the salivary response found by Pavlov (1927). The ability of humans to interpret phrases and action abstractly allow for a wide variety of responses of this sort.

Games tend to be more complex than the above examples. The pattern of call and response within a jazz performance, for example, does not generate results that are one-to-one. The play is structured, but it is also open-ended. A particular signal can emit a variety of responses from an agent depending upon the environment in which the signal is received and the state of that person’s knowledge (Rescorla, 1988). Some responses may even generate novelty! While the response of any individual may be difficult to predict, when human agents communicate and interact, the system formed by their interactions tends to converge upon a circumscribed set of responses that define play within a given game:

The rules of a language game are constraints, not marching orders. The rules of chess constrain us. Only certain moves are allowed. But the moves we make within the constraints are freely chosen. . . . Good players typically adopt rules of thumb, however, to guide their choices. Depending on the purposes of the analyst, these rules, too, may be thought of as part of the operative set of language games governing play of the game. (Koppl & Langlois, 2001, 290)

Rules that govern social games are not static. There is always room for development of the patterns of action that arise within the game. Agents may generate novel play that falls within the rules that govern interaction. Agents, sensing opportunity, may also take novel action that implicitly reinterprets the rules that govern play.
Rules guide both action and interpretation for observers both within and outside of a game (Koppl & Whitman, 2004; Hayek, 1962). In a game of basketball, we expect that if a player places both hands on the ball after having dribbled, that player can take two steps before either passing or shooting, or he must cease movement across the court. After stopping, the player cannot legally dribble again. Given this rule, a player defending against someone who has ceased dribbling will expect that the players range of motion has become constrained. This expectation coordinates the actions of both players. It is built upon knowledge of requisite objects, rules that constrain the use of these objects, and patterns perceived as arising within these rules.

**Modeling Play and Learning within Games**

Given a representative ontology of a game and the appropriate statistics, an interested party can create an agent-based model of high fidelity. For a game of basketball, statistics of interest might include the probability of a foul being called on a defender either per unit of time spent defending against a particular player or per shots guarded against a player. Another may include the probability of making a shot, assuming it is not blocked, from a particular area of the court. More significant for the framework described here, an agent-based model will also include player decisions contingent on the arrangement and motion of objects in the environment. For example, maybe when guarded by two players at the top of the key, Stephen Curry will pass the basketball 50 percent of the time, shoot it 25 percent of the time, drive to

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25 Koppl and Whitman discuss *homo basketballicus* in this manner: Suppose we wish to describe the on-court behavior of professional basketball players. We construct a model under the assumption that basketball players are motivated solely by the desire to win basketball games. With this assumption we have defined an ideal type, which we will call *homo basketballicus*. This ideal type, combined with knowledge of the rules of basketball, leads us to certain conclusions about his play. For instance, he will likely pass the ball to another player when the other player clearly has a better chance of making a basket.
the hoop 15 percent of the time, and move to another area 10 percent of the time. Or a model may select plays based on the probability of some play being run by a particular team given the arrangement of players on another team. The better the modeler is at identifying circumstances of statistical significance to outcomes, the more accurate will the predictions of the model be.

Once the appropriate rules guiding agent action are defined, a model of the game can be run numerous times in order to generate the probability of a team winning or losing.\textsuperscript{26}

Or consider a model of traffic jams. In such a model there is a critical threshold at which average rate of movement of vehicles tends to slow at a greater rate than the rate of increase of vehicles on the road. A core theoretical model like this one can be integrated with real world data to predict patterns of traffic on a given road or expressway (Balmer, Cetin, et. al., 2004). In each of these models, however, the structure of agent knowledge is static.

The aim of this paper is to develop an abstract framework for modeling human action where the knowledge driving preferences changes to match the environment. That is, agents learn as they interact with the environment. The example of a basketball game is limited in that it is difficult to accurately model the manner in which particular players will learn from one another. A model could include learning within the game, but that model will more than likely not generate results that accurately predict outcomes in the game. Point prediction in a robust theory of society is a secondary goal that must follow first from understanding of the phenomenon in question.\textsuperscript{27} We are interested in a model that allows agents to adjust their knowledge so as to allow for systemic coordination. In an agent-based model of basketball, this

\textsuperscript{26} These simulations are essentially the equivalent of a basketball videogame where “computers” control the play of each team.

\textsuperscript{27} This is not to argue that tools for prediction generated from a purely positivist framework are not useful. Their explanatory power is limited to a different and smaller domain than that of pure theory.
may be accomplished by allowing an agent to adjust the value of a parameter whose use is demonstrated by other agents. For example, maybe a certain agent only defends against a moving player by maintaining a close distance between himself and the player he is guarding. Upon observation of other players, the defender notices that he may adjust the distance according to the opposing player’s distance from the basket. Likewise, a player may experiment with changing his direction and speed in order to coordinate with another player moving across the court.

A similar strategy for modeling is used in a heuristic rendition of Sugarscape (Caton 2017) where agents innovate and copy strategies with unique parameter values. As the environment, which includes other agents, changes, so too does the composition of strategies present along with composition of parameter values that guide these strategies. Changing strategies represent changes in knowledge that typically alter the means and ends of an agent at a given time and place. In a given context, the agent chooses next act according to the arrangement of elements in the environment as well as those in the agent’s mind.

Theory of Learning Process

For a game like basketball to be played at all, every agent must have some basic knowledge of the rules and of strategies by which he or she might coordinate with another player. Each of the players on the court has a shared mental model (Denzau and North 1994) that includes the goals within the game and its rules and strategies. These mutually guide agent interactions. This set of behavioral rules, evidenced by the actions of players with knowledge of the rules constraining play, represents an institution. This knowledge is the interface by which

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28 Thanks to Anna Zaytseva and Melissa Eitzel whose discussion helped me to develop the structure of this model at the Santa Fe Institute in 2015.
agents interact with reality, and therefore, with one another (Simon 1969).

Cues within a game facilitate communication and planning between agents. In his discussion of language within a firm, Arrow (1974) refers to these as codes and recognizes their role in communication:

Learning a foreign language is an obvious example of what I have in mind. The subsequent ability to receive signals in French requires this initial investment. There are in practice many other examples of codes that have to be learned in order to receive messages; the technical vocabulary of any science is a case in point.

Within an organization, the formulation of a special language serves both roles of communication, as well as secrecy and separateness. It’s play helps to identify those who are in the in-group (Sowa 2007; Koppl 2002, 74). “Any in-group has a relatively natural concept of the world which its members take for granted (Schutz 1946, 464).” To the extent that these concepts are unique to the group, those outside the in-group are not privy to these concepts or the language used to describe them. Divisions of this sort exist at a variety of scales.

This pattern of shared knowledge and means of communication allows for knowledge creation within groups and organizations. It allows for learning. The learning process can be divided into three stages:

1. Discovery: Generation of a novel idea or change to an existing idea
2. Interaction: Dialectic among agents of interest
3. Integration: Assimilation of innovation into understanding of agents and/or into external technology.

The entrepreneur drives this process. Concerning the generation of a change in understanding, Ikujiro Nonaka (1994), in a manner reminiscent of Viennese tradition, identifies:

The prime mover in the process of organizational knowledge creation is the individual. Individuals accumulate tacit knowledge through direct “hands-on” experience. (21)
He notes that while tacit knowledge plays a significant role in the development of personal knowledge, experiences that generate such knowledge:

Have to be counterbalanced by a further approach to knowledge creation that raises the quality of explicit knowledge . . . The interaction between knowledge of experience [tacit] and rationality [explicit] enables individuals to build their own perspectives on the world. Yet these perspectives remain personal unless they are articulated and amplified through social interaction (22).

The development of knowledge starts with the individual, however, it is only of use to others if that individual finds a way to share this knowledge. Sharing demands a common language as well as common understanding that facilitate the transmission of new knowledge (Grant 1996, 116). Common understanding does not imply identical understanding. Agents must have a sufficient degree of common understanding engage in a dialectical process that allows those involved the opportunity to work out differences of interest (Rosser 2000). They discuss and focus interaction around the new idea or innovation and posit alternatives. Eventually, the group may converge upon common understanding, in which case the new idea or innovation is integrated into the group’s common knowledge. The three steps are discussed in detail below.
After the new idea is shared between two agents, the process of interaction and integration duplicates itself across populations and at different levels.

**Discovery**

The human agent is a node that gathers, interprets, and shares information. She takes action based upon her accumulation and interpretation of information. Intelligence lies in the ability to act in a manner that coheres with the environment. Humans search for patterns and meaning in their environment that allow them to predict likely future states (Hayek 1964).

Discovery is a result of search by an individual agent (Nonaka 1994; Floyd and Wooldridge, 1999). When an agent discovers new information, he must integrate it into his own
framework. This requires a process of interaction within the agent as he must identify the relationship between the new information and the existing framework. The information must cohere with the mental model, or else be disregarded absent a transformation of the mental model. In this sense, even in the process of discovery we see interaction and integration occurring between the agent’s “mental model” and the outside world (Johnson-Laird 1980). The agent himself facilitates this process. He restructures his model through an ongoing process of trial, error, and reinterpretation (Hayek, 1955; Johnson-Laird 1980, 81, 108). By this process, he hopes to overcome ontological uncertainty.

It is likely, that the agent will have to employ different mental models depending on context. The level of coherence between mental models depends on the preferences of the agent in light of the demands of his environment. For this reason, many people are comfortable with participating in a religious group without worrying that the logic of their faith contradicts the logic of science. Given apparent contradictions between models, some may develop a rule where, in the case of a particular type of contradiction between models A and B, defer to model B. Others may take this further and engage in apologetics so that the models more faithfully

29 Hayek argues:

Any model defines a certain range of phenomena which can be produced by the type of situation which it represents. We may not be able directly to confirm that the causal mechanism determining the phenomenon in question is the same as that of the model. But we know that, if the mechanism is the same, the observed structures must be capable of showing some kinds of action and unable to show others; and if, and so long as, the observed phenomena keep within the range of possibilities indicated as possible, that is so long as our expectations derived from the model are not contradicted, there is good reason to regard the model as exhibiting the principle at work in the more complex phenomenon. (206)

Concerning the relationship between the validity of a mental model’s logic and learning, Johnson-Laird notes “if you are logically prudent, you attempt to test your mental model to destruction (81).”

30 That is, uncertainty generated by a mismatch between the agent’s mental model and the reality it is intended to represent.
cohere to one another. As the logic of a given model or models has attained an adequate level of coherence, the new idea is ready to be communicated to other agents.

**Interaction**

Once the agent believes that he has sufficiently worked through the logic of the transformed ontology, this mental model must interact with the models of others. Much of the knowledge distributed between, and even within, agents is conflicting or, at least, not obviously compatible (Hayek, 1945; Dennett, 1991). Agents engage in rhetoric to convince one another to adjust their beliefs. As Donald McCloskey argued, rhetoric is “the art of discovering good reasons, finding what really warrants assent, because any reasonable person ought to be persuaded. . . . Rhetoric is exploring thought by conversation (1983, 483).” We must communicate our ideas in a manner that can be understood by the receiving party. This requires that agents within a group converge on a common language to describe reality.

Not all communication is verbal. An agent may engage in *rhetoric by practice*. If he has discovered a superior form of action, those around him may notice that he has accumulated more wealth or is happier or that his actions seem effortless in comparison. Others may attempt to copy and learn from such an agent just by being in his presence. If one’s practice draws a following, even if only locally, he functionally acts as an exemplar agent (Dekker, 2016).

The agent conveying this unique interpretation of reality has worked to overcome ontological uncertainty that arises due to a mismatch between each agent’s mental model. An aligning of models represents an aligning of expectations (Lane & Maxfield, 2005). By engaging in rhetoric, the agent shares an idea in a manner that may convince another party to transform

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31 See St. Augustine, Aquinas, (See if you can find a modern source that confronts this issue).

32 Dennett refers to consciousness as containing ”multiple drafts”.
his or her mental model. Sharing agents can work to overcome ontological and semantic uncertainty by conversation. They continually reformulate their mental models to cohere with reality and the models of one another. The stage of interaction will often lead to a return to the first stage of discovery as both or either of the agents reinterpret facts in light of communication with one another. There is no guarantee of success in this process, though the process of competition and selection tend to promote convergence to strategies that promote survival in a given environment.

Integration

Integration occurs when both agents come to act from a framework that includes the new idea or ideas. This does not mean that their mental models are identical. Rather, they come to agree on interpretation of an aspect of reality, say, concerning how a piece of machinery should operate or the strategy their business should employ. The development of a common understanding improves the ability of agents to cooperate with one another as their action is coordinated around the same set of rules that govern behavior, plans, goals, etc... Once agreement has been arrived at, agents may discover new problems that require the process to occur again within the same group. Or, a group may attempt to influence how another group sees reality. They can investigate reality from a new perspective and analyze elements of reality of which they were not previously aware.

At higher levels, integration requires acquiescence of a perspective by those in leadership positions. Acquiescence by leaders is not independent of the beliefs of those subject to them. Likewise, agents who submit to the rule of a particular leader also submit substantial proportion of their beliefs to shaping by the leader. While de jure leaders may play a significant gatekeeping rule, they do not comprise exhaustively the set of leaders. “They are not people at
the top of things so much as people at the edge of things, not leaders within groups so much as brokers between groups (Burt, 1999).” Leaders occupy positions within networks that allow them to connect to distinct groups (Granovetter, 1973). These leaders exhibit a high degree of prestige that allows them to exercise a similarly high degree of influence on the beliefs and practices of others (Henrich & Gil-White, 2001; Hodgson and Knudsen 2010, 165). There is a mutual process of shaping beliefs that goes on between levels of association. Once formation of a particular opinion reaches a significant threshold within a given population, the belief tends to be absorbed by those who would otherwise hold a different belief (Asch, 1955; Henrich & Boyd, 1998).

**Competition and Selection**

Our agents are carriers of strategy. Their survival is dependent upon their programming. This includes the ability of agents to reprogram themselves. Agent survival is subject to one rule: the inflow of resources consumed must be greater than zero and be equal to or exceed the outflow. Biological agents need to inherit structure that allows them to acquire sufficient nourishment in the form of calories and nutrients. Again, the term sufficient means that the inflow of nutrients required for survival must meet or exceed the outflow. Survival in the competitive market requires the use of strategies that generate more value than would be generated by the next best competing strategy.

This applies to firms, which are also agents. Competing firms\(^3\) must generate value that exceeds the opportunity cost of their use of resources. The employee at a firm must value his wage, which includes both monetary and non-monetary compensation, more highly than the

\(^3\) I refer to firms in the sense of Foss and Klein who describe firms as agents comprised of capital combinations (2012).
wage that the employee expects to receive in service of a competing firm. Likewise, revenues earned from the sale of products must exceed the monetary costs of production.

The survival of a firm is an indicator of the fitness its strategy. Growth of a firm augments this signal. If some set of knowledge is to be described as fit for an environment, it will spread to observing agents. The process of adoption by others is by no means ensured for any set of knowledge. Nor is such an idea guaranteed to be continually maintained by an agent who carries it. Knowledge that is helpful to an agent for a brief period may lose its usefulness. The ultimate test of knowledge is its ability to survive over long periods of time. Knowledge that promotes fitness must be replicated in the manner described above. Knowledge is an integral part of the evolutionary process (Campbell, 2013; Dewey, 1908).

The process of evolution at the level of the agent takes the general form:

Replicator → Interactor → Fitness (Hodgson & Knudsen, 2010, 107)

An interactor is the unit that is reproduced. These include, for example, “organisms or business firms (93)”. The replicator is a particular set of knowledge that is replicated. Genes are replicated in an organism much as skills and routines are replicated in a firm. That knowledge promotes structure internal to the interactor that promotes survival in a given environment. In an organism this is a gene. In a firm this may be some routines, norm, language set, etc... In the case of an organism, the knowledge replicated leads the organism to instantiate structure that mediates between conditions of its internal and external world. Within a firm, the replicator is often itself knowledge embodied by routines and norms that, when duplicated, will likely need to adapt to the new environment in order to promote fitness. Individuals within the organization are able to cooperate as a result of these shared norms and mutual practice and development of routines (Nelson & Winter, 1982, 96-136; Hodgson & Knudsen, 2010, 78-88).
They represent “organizational memory”. The result of this cooperation, dependent on knowledge present in norms, habits, and routines impacts the fitness of the organization.

Table 1

<table>
<thead>
<tr>
<th>Steps of Learning Process</th>
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| Discovery                 | • New idea or extension of existing idea is generated by an individual.  
                            | • Extension may consist new application of an existing idea that will alter technologies, where technologies include a broad range phenomena including but not limited to systems of governance, engines, computer processors. |
| Interaction               | • There will likely exist disagreement concerning the extension and/or its application.  
                            | • Agents engage in dialectical process with intention of overcoming disagreement. Intention may or may not be amenable to the concerns of both parties. |
| Integration               | • In a purely dyadic relationship, the process is complete when both agents come to a common understanding, representing a concept around which cooperation centers.  
                            | • At the scale of the group, when a sufficient number of members adopt common understanding, the remaining members will tend to adopt the same understanding. |
### Table 2

**Categories of Interactions**

<table>
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<tr>
<th>Scale of Interaction</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>Dyadic</strong></td>
<td>Two individuals discuss discrepancy in understanding, each mutually adjusts his or her understanding until converge on common understanding concerning topic of interest. Dyadic interactions also comprise the core of the interaction-integration process at the group and inter-group levels.</td>
</tr>
<tr>
<td><strong>Intragroup</strong></td>
<td>If sufficient number of individuals in group adopt a particular understanding and there is no competing camp, the remainder of the group will tend to adopt the dominant understanding.</td>
</tr>
<tr>
<td><strong>Intergroup</strong></td>
<td>Convergence requires entrepreneurship, typically by those agents whose pattern of relationships comprise a structural hole (Burt 1999; Granovetter 1973). Dyadic relationships that span between networks that are otherwise unconnected represent intergroup interaction</td>
</tr>
</tbody>
</table>

### Structure, Features, and Dynamics of Knowledge at the System Level

**Institutional Dynamics**

Just as influential persons “at the edge of things” can sway the beliefs of groups, so can individuals who have significant influence over formal institutions. Institutions are external manifestations of agent knowledge. Causation operates both from the bottom up and the top down (Lopez & Leighton, 2013). Douglass North observes the relationship between agent belief and institutional structure:

There is an intimate relationship between belief systems and the institutional framework. Belief systems embody the internal representation of the human landscape. Institutions are the structure that humans impose on that landscape in order to produce the desired outcome. Belief systems therefore are the internal representation and institutions the external manifestation of that representation. (2005, 49)
Whose ideas come to dominate this “external manifestation”? North tells us that “when conflicting beliefs exist, the institutions will reflect the beliefs to those (past as well as present) in a position to affect their choices. . . (50)” If there is not agreement among those in control, conflict may occur concerning the structure through which the power of the state or some other institutional structure is implemented.

These social structures exhibit causal efficacy over the actions and perceptions of agents subject to them. They represent part of the environment with which an agent interacts. They indicate beliefs of other agents who adhere to them. The outcome of the conflict over the operation of institutions changes the constraints of an agent’s action and understanding of the world. In the case where mental models interact without the mediation of formal institutions – i.e., informal institutions – changes to agent mental models tend to be the result of voluntary action given the context from which it emerges. This is not the case when governance mechanisms, and the force that underlies them, is employed to implement rules and structure that cohere with the shared mental models and preferences of a particular agent or group of agents over those of other agents. While agents subject to the institution still act voluntarily, changes in incentives accompany the changes in structure. Institutions determine the cost structure of an array actions that an agent might consider. A change in institutional structure and incentive represent a change in the agent’s environment. Institutions exhibit causation by constraining or altering the array of options that an agent considers to be available to himself. They place constraints on what states of reality agents consider to be realizable and reinforce this through the provision of incentives and disincentives. These promote shared understanding.

Beliefs, and knowledge contained in those beliefs, are absorbed and reinforced by the
agents subject to them. This active participation moves the belief from being a phenomenon that rests in the mind of an individual to an institution whose existence and significance in the world cannot be denied. The social world is filled with these. Some of these are simple, as in the coordination game where agents must choose the same strategy (i.e., drive on the right side of the road). In other cases, agents come to communicate through a common object whose value changes. The value helps guide the decisions of an agent. Consider cars at a traffic light. Drivers learn that they should continue through an intersection when the light is green. They should stop when the light is red. Agents do not need to communicate to coordinate, they need only act according to the meaning commonly imbued to the color of each light. Prices play a similar role as consumers and producers must adjust their use of resources in light of changes in income and prices.

By the example of the traffic light, we observe that the ontological description of an institution matches the ontological description of agent logic. Just as agents understand that, concerning non-social objects, \( X \) counts as \( Y \) in \( C \), we see that the statement also holds for the interpretation of institutional objects. The agent interprets that red light as meaning that she must stop her vehicle before the start of the intersection just ahead. A red light, \( X \), counts as a signal to stop, \( Y \), when my vehicle is approaching the intersection over which the light hangs, \( C \). If a city council decides to place stop lights or stop signs at new intersections, we expect that passing vehicles will obey the signals represented by the new light in the same manner as lights that existed before. The difference between the elements of a strictly personal ontology and the elements of an institutional ontology is simply that the latter are shared while the former refer to the understanding of a single agent.

If an institution ultimately represents a belief or set of beliefs that are submitted to by
some group of agents, institutions themselves represent a special class of knowledge. Thus, the pattern of knowledge creation and transfer described so far thus holds changes in ideas and institutions. Peter T. Leeson (2014) identifies that the British Officer Samuel Macpherson played a critical role in replacing the institutions of human sacrifice among the Konds who inhabited part of India by means of an interaction between groups (Table 2). He was unable to accomplish this by working solely within a given village, but rather served as the primary node of communication between villages in the process. Macpherson filled what Burt (1999) refers to as a structural hole; that is, a position of contact between groups who do not communicate between one another. The actor who occupies a structural hole can be a powerful broker between interested parties that he or she connects, and is therefore in a position to influence political outcomes (Christopoulos, 2006; Christopoulos & Ingold, 2015; Batilana, Leca, & Boxenbaum, 2009). Macpherson used this role to guarantee the execution of justice and property rights absent the system that had been dependent upon human sacrifice. This represented an attempt to remove an undesirable element from the Konds’ system and integrate a more humane innovation in its place. By doing so, he was able to help integrate the Western notion of human rights into a system where violation of such rights was integral to its functioning.

Leeson also highlights the role of belief reinforcement within an institution. He recalls from Macpherson that “each head of house rolled his shred of flesh [from the sacrifice] in leaves, and buried it in his favourite field (156).” This served the role of “extending knowledge of the community’s immolation to the inhabitants of villages who were not themselves able to participate [emphasis mine] (156)” and thus ingrained the society’s institutional structure and the human sacrifice around which it centered into the beliefs and habits of those subject to it.
To change the institution required that individuals in Kond society adopt new beliefs.

Macpherson helped motivate integration of a Western ideals into the Konds’ system by coordinating the practice of leaders across their society to cohere with human rights. In return the British offered to administer a system of justice (161-62).

As the story of Macpherson and the Konds indicates, our investigation of a process whereby an agent’s mental model interacts with the mental models of others through collective or coalescent action and belief, thus, leads us to a process of institutional formation and observation of their causal efficacy. Beliefs not only guide institutional formation, but may also change as a result of changes in institutional structure. The organization that emerges from shared understanding or submission to a formal institution is a form of social capital. This carries with it advantages:

Social capital represents the ability of actors to secure benefits by virtue of membership in social networks or other social structures. At an organizational level, benefits include privileged access to knowledge and information, preferential opportunities for new business, reputation, influence, and enhanced understanding of network norms. (Inkpen & Tsang, 2005, 150)

These privileges come alongside obligations upon participants:

Human institutions are, above all, enabling [emphasis author’s], because they create power, but it is a special kind of power. It is the power marked by such terms as: rights, duties, obligations, authorizations, permissions, empowerments, requirements, and certifications. (Searle, 2005, 10)

In the case of the Khond’s, each person in the village was obliged to participate in the system on some margin. Likewise, in the new system, participants were required to submit to legal enforcement by the British. In order for institutions to function, agents must embrace their roles as defined by their rights and duties of office. They must act upon the belief implied by their submission to the institution, its rules, and its language.
Games in and Between Networks

The existence of groups that generate and are subject to common knowledge innately contain a network structure. This network structure represents paths through which resources, including knowledge and information flow. In the case of Khond society, a network of villages were linked by the customs that centered around a system of human sacrifice. Those villages involved in the system shared common norms, beliefs, and practices, reflecting convergence of norms common to a group (Table 2). The same tendency holds for any institution. For example, Blondel, Guillaume, Lambiotte, and Lefbvre (2008) identify groups according to shared languages within groups of cell phone users. They found that communities that they examined in Belgium tended to center around one language or another. “For all but one community of more than 10000 members,” they report, “the dominant language is spoken by more than 85% of the community members (7).” They go on to note that of the two dominant language groups, French and Dutch, significant structural differences are detected in networks. This “seems to indicate that the two linguistic communities are characterized by different social behaviours and therefore suggests to search other topological characteristics for the communities (9).”

While this finding may seem obvious, the connection between relatively homogeneous norms and institutions in communities and a method for identifying them has received little attention by social theorists, though it has received attention in organization and complexity sciences. The existence of such communities should be of no surprise if we take seriously the notion of a language game. A language and the rules that govern its use must be common to agents participating in a particular game or set of games. According to Mauws and Phillips:

Organizations should not be approached as objects but as processes, as ongoing social accomplishments that are sustained through constant interaction . . . the knots in the fabric of organization are language games and the usage of a term (or gesture or
practice) is mediated by the language game in which it occurs. . . . Organizational members do not experience organizational membership as an external aspect of their life, but rather live it and are shaped by their interactions with the people and objects which make up the organization. (1995, 332)

They go on to explain that different organizations themselves comprise different uses and rules of language. “It is through language games that entities come into being (332).” Agents within a network or organization themselves carry bits and pieces of understanding that coalesce into a common map of the organization. The elementary bits of this map that are shared amongst a substantial portion of agents serve as a means of communication as well as a marker of distinction for the group.

This phenomenon does not seem to have been lost on some post-modern philosophers. Jean-Francois Lyotard notes that there has been much misplaced pessimism in the supposed identification of growing isolation in modern society. All groups share a special means of understanding and interaction between their members:

A self does not amount to much, but no self is an island; each exists in a fabric of relations that is now more complex and mobile than ever before. . . . Language games are the minimum relation required for society to exist . . . the quest of the social bond, insofar as it is a question, is itself a language game, the game of inquiry. It immediately positions the person who asks, as well as the addressee and the referent asked about: it is already the social bond. (Lyotard 1984, 15)

Language, in the broadest sense, is a necessary component of a group. Language games represent the dynamic links between the agents that comprise a group. Those able to mutually participate in these language games exhibit shared and compatible knowledge. The boundary of a group is coterminous with the boundary of some game or collection of games. We may then define a social group as an entity comprised of agents who collectively experience “a network of meanings” (Hassard 1994, 307) in regard to shared language and “a network of significations” in regard to relationships that comprise some organizational structure (320; Danford, 1978, 73-
The concept of shared mental model, popularized amongst economists by Denzau and North (1994), carries with it substantial content that is necessary for the functioning of any social world.

While some games are confined within a given network, others reach across networks. The language game that contains perhaps the broadest reach is the game of market pricing. The first person who appears to have recognized this relationship is Saul Kripke (1982, pp. 112-113, n89). Others include David Bloor (1997) and Roger Koppl (2002). Kripke notices that there seems to be “a certain analogy between Wittgenstein’s private language argument and Ludwig von Mises’s celebrated argument concerning economic calculation under socialism.” Prices are set, not by a central node, but by conversation between agents who participate in the market process (Mises, 1990; Hayek 1935, 1945). Mises and Hayek recognizes this fact. David Bloor identifies the former:

Thus: ‘Prices are . . . social phenomena as they are brought about by the interplay of the valuations of all individuals participating in the operation of the market’ (HA: 331). Price is not like, preference, an individualistic fact, but a collective fact derived from specific form of collective organization. (1997, p. 75)

The value of prices are transformed by the interaction of market participants. As with the generalization described earlier, agents engage in dyadic interactions that reflect their beliefs. When bargaining agents come to an agreement, they have converged on some perceived value of the good being exchanged. Just as groups tend to converge on sets of common knowledge, participants in the game of market pricing and exchange converge upon a bounded range of prices (Gode & Sunder, 1994; Caton, 2017). Unlike social norms tied to a particular group or society, this game is played by any agent who engages in exchange that is part of a chain of exchanges that spans between groups and societies. To the extent that mutual participation in a
language game represents a “social bond”, the game of market pricing is certainly the most inclusive game connecting agents and groups both close and far.

**Experts and Dispersed Knowledge**

Actors who comprise a community are not of equal knowledge and ability. As discussed earlier, some *expert* agents carry particular knowledge that they may convey to other agents who lack this knowledge. Some of these are paragons of leadership and ability. John Wooden, coach of UCLA’s basketball team, for example, is commonly referenced as a model for leadership (Wooden & Carty, 2005). John C. Maxwell has served a similar role with his *Laws of Leadership* (1998). Persons in need of such skill attempt to emulate his practice and principles. It may be inefficient for every person alive to learn the skill taught and practiced by Wooden and Maxwell as much as it would be inefficient for every person to earn a Ph. D. in engineering.

Acquiring knowledge carries with it an opportunity cost.

Knowledge must be distributed for there to exist a diversity of ideas that are able to compete with one another. Only through processes of experimentation and competition is a population of agents able to take full advantage of its creative potential (Hayek, 1946, 1960). We can think of this dispersion as existing in multiple layers. The most obvious is that only particular individuals hold certain types of knowledge. I pay a mechanic to work on my automobile because I trust his knowledge of the working of my vehicle better than I trust my own and because the expected cost of relying on my own expertise is higher to me than if I do rely on the mechanic. In developed and developing societies that have achieved modest progress, the skills offered by mechanics tend to be available to those who need and can afford them.

There is another sense in which knowledge is dispersed. Some expert knowledge may
belong to certain agents with a particular group, but that knowledge may not be widespread. Since particular bits of knowledge are dispersed across networks, locked behind the shells of particular language games, there exists a challenge of gathering and combining different concepts that, in natura, are separate from one another. Entrepreneurs may discover benefits from the mixing of these ideas. The dispersed nature of this sort of knowledge is especially apparent within groups of academics whose ideas do not dominate the discipline but do comprise a school. Elinor and Vincent Ostrom, for example, gathered ideas from Austrian economics, philosophy, and political science in order to build powerful analyses of federalism and the commons (Ostrom, V., 2008; Ostrom, E., 1986, 1990).

Diversity within the population supports a plethora of ideas and understandings that can be drawn from to promote productivity and creativity. In regard to productivity within a firm, Scott Page argues that “when a collection of people work together to solve a problem, and one person makes an improvement, the others can often improve on this new solution even further. . . Diverse perspectives and heuristics improve problem solving (2007, pp. 13-14).” Those who are able to bring these diverse perspectives together stand to benefit.

This knowledge is not costless to access. Groups develop their own set of language games to cooperate. These will often be unique. Thus, integration of knowledge across networks requires ability to play a diverse collection language games not germane to a single group.

**Institutional Feedback and Knowledge Transmission**

This framework allows for the consideration of the factors that promote the transmission of knowledge such that agent actions are constrained by objective circumstances, which include each’s own actions. Good institutions tend to provide each participating in them a channel through which he or she can modestly influence outcomes at the local and, to a lesser
extent, system levels. In democracy, channels for participation and communication include voting, campaign donations, and reciprocal favors by those who hold power to accomplish such favors. Authoritarian regimes a smaller set of these channels. In both cases in government, the feedback of the action of an officeholder or office holders are not directly linked to the economic outcomes they generate. Rather, they are linked to the incentives of office. Actions within the market order, though they may be temporarily shielded by layers of corporate bureaucracy in some circumstances, are subject to feedback of greater clarity and speed compared to the institutions that comprise the state (DeCanio 2014).

Feedback is a mechanism by which alert agents can adjust their activity to match objective circumstances. In the context of democracy, feedback tends to be less easy to interpret as goods provided by government tend to come in bundles and are paid for indirectly through votes and taxation (638). Markets, on the other hand, provide information at a higher frequency and with greater clarity in comparison to the state. Consider Hayek’s example of the price of tin. If for some reason, the price of tin rises, purchasers of tin are forced to economize on their use. Some producers may substitute away from tin toward another metal and thus alleviate stress placed on the supply stream of tin induced by their demand. In like manner, firms may be forced to alter their strategies for the consumption and production of a metal whose price has increased. For example, elevated gold prices precipitated the development of the cyanide process, which dramatically lowered production costs and increased overall output (Rockoff 1984). The latter case is interesting as one set of knowledge – prices – led to a radically restructuring of another set of knowledge – gold production.

**Conclusion: An Agenda for the Marriage of Complex Methods and Methodology**

This framework has identified two parallel lines of thought. Primarily, it has drawn from
the literature to provide a theory of knowledge. This theory takes Wittgenstein’s language game as its starting point and delineates the elements, relationships, and processes implied by it. This framing allows for a dynamic interpretation of (not necessarily independent from one another) knowledge, individual action and interaction generated from this knowledge, and institutions that embody this knowledge. This stream of thought meshes with the second: development and use of complex methods. These methods include agent-based modeling and network analysis. These allow for the observation of the formation of knowledge and institutions both experimentally and empirically.

Knowledge has structure. It exists within the human mind. It is embedded in action, interaction, and the environment. Knowledge is dispersed across society. Alternately, we can refer to knowledge as technology. It is the logic implied by useful social and physical configurations. This logic is abstract. It is subject to change over time. As such, it provides constraints as well as a space for creativity for those who employ and are subject to it. Provision of structure, vocabulary, and methods for modeling knowledge in any and all of its forms opens the door to the development of finely detailed economic and social theory whose applied models cohere closely to the reality it observes.
Citations


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Biography

I am a graduate lecturer and candidate for a Ph.D. in economics at George Mason University. I have been recipient of the F. A. Hayek Fellowship from Mercatus, the I.H.S. Humane Studies Fellowship, and their Summer Research Fellowship. I hold an M.A. in Economics from San Jose State University where I was a participant in the Student Faculty Partnership and received the Award for Excellence in Economics. I have co-edited Macroeconomics, a 2 volume set which is a collection of essays and primary sources that represent the core of macroeconomic thought. I have also published articles in the Review of Austrian Economics and Advances in Austrian Economics and published book reviews for EH.net, The Journal of Markets and Morality and History: Review of New Books.