

University of Missouri-Columbia
(MUU) Ellis Library - ILL

Borrower: UUS

Lending String:

CSL,DLM,*MUU,TXH,KKU,AMH,LFM,NJS,TEU,
TJC,TSC

ILL Number: 191700490



Patron:

Charge Maxcost: 25.00IFM

Email: ILSRQST@usu.edu

Ariel: 129.123.124.220

Odyssey: 129.123.124.234

Ship to:

Merrill-Cazier Library- ILS

Utah State University

3045 OLD MAIN HILL Room 118

Logan, Utah 84322

United States

102 Ellis Library - 1020 Lowry

TN#: 918817



Call #: HB98 .O94 2015

Location: MU Ellis NOT CHECKED
OUT

Book/Journal Title: The Oxford
handbook of Austrian economics / The
Knowledge ProblemThe Oxford
handbook of Austrian economics /

Volume: Issue:

Month/Year: 2015 **Pages:** 45--64

Article Title: The Knowledge Problem

Article Author: Lynne Kiesling

Interlibrary Loan – Access Services Department
University of Missouri Libraries
Columbia, Missouri

Copyright Notice

The copyright law of the United States (title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specific conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "Fair Use," that user may be liable for copyright infringement.

For more information, visit copyright.gov

CHAPTER 3

THE KNOWLEDGE PROBLEM

LYNNE KIESLING

INTRODUCTION

WE typically associate the knowledge problem concept with F. A. Hayek's seminal article "The Use of Knowledge in Society" (1945). Hayek argues that the fundamental economic problem societies face is not the allocation of a given set of resources based on a given set of preferences and technical capabilities; instead, the coordination of decisions and actions among interacting individual agents with diffuse private knowledge and plans forms the basis of economic activity. The diffuse and private nature of knowledge hampers such plan coordination, but out of human interaction, institutions emerge that enable decentralized coordination. Prices and market processes compose an institution for coordination in the face of the knowledge problem. Moreover, Hayek argued, knowledge transcends "scientific" information, there is no given and uniform set or distribution of data, and such information fails to capture all knowledge relevant to both static and dynamic decision-making and coordination.

Hayek's substantial insight in this work, one that has become largely incorporated into mainstream economics, is that the price system operating through market processes is an effective, parsimonious (but not perfect) means of generating, signaling, and aggregating such knowledge. Prices cannot convey all individual knowledge pertinent to a particular economic decision, but they do serve as knowledge surrogates by communicating some private knowledge (Horwitz 2004). Coordination of individual actions and plans emerges as a beneficial consequence of the price system; thus, the price system and market processes enable emergent, or unplanned, order.

While this argument captures much of the substance of the knowledge problem as both a coordination problem and an epistemological issue, Hayek and other scholars developed the concept more deeply, including the idea that knowledge may be contextual and

may not even exist outside of the economic process. Private knowledge includes knowledge of “time and place,” which is difficult to articulate, communicate, and aggregate. Its highly contextual nature can make private knowledge fleeting and ephemeral. Thus, the knowledge problem has two main components (Thomsen 1992, 16–17):

- *Complexity knowledge problem.* The difficulty of coordinating individual plans and choices in the ubiquitous and unavoidable presence of dispersed, private, subjective knowledge.
- *Contextual knowledge problem.* The epistemic fact that some knowledge relevant to such coordination does not exist outside of the market context; such knowledge is either created in the process of market interaction, tacit knowledge that is not consciously known (Polanyi [1966] 2009), or inarticulate knowledge that is difficult to express or aggregate.

The distinction between knowledge and information has been important for twentieth-century economic thought, although it is a distinction that modern information theory has blurred (Thomsen 1992). Information can be acquired, although at a cost, but not all decision-relevant knowledge is consciously knowable or can be acquired explicitly. Boettke (2002, 166–167) illustrates this distinction with an example of an engineering student looking for a model to solve a problem. Treating this as an information and search cost problem, she will search the library for a model and search as long as the expected marginal benefit is at least as large as marginal cost. However, treating the problem as an information problem ignores her development and creation of new knowledge in the process of her problem solving, such as her creation of new models; consider also the variety of dispersed engineering students coming up with different new knowledge in the process of their activity.

The provenance of the knowledge problem idea is older and is more broadly applicable than the aggregation and transmission of diffuse private knowledge through prices. In fact, the knowledge problem is a deep epistemological challenge, one with which several scholars in the Austrian tradition have grappled. This chapter provides an overview of the development of the knowledge problem as a concept that has both complexity and epistemic dimensions, its relation to and differences from modern game theory and mechanism design, and its implications for institutional design and political economy.

HISTORY OF THE IDEA: THE COMPLEXITY KNOWLEDGE PROBLEM

Ludwig von Mises’s reading group in Vienna provided an interdisciplinary, intellectual focal point for the development of many ideas related to the knowledge problem. Meeting between 1922 and 1934, this group included Hayek, Alfred Schutz, Oskar

Morgenstern, Fritz Machlup, and other economists, sociologists, and psychologists working and studying in Vienna in the 1920s.

Schutz's ([1932] 1967) analysis of meaning and how we create intersubjective knowledge provided an early and significant foundation for the role of the knowledge problem in Austrian economics. Schutz worked primarily to extend and clarify Max Weber's methodology of the social sciences and his "ideal type" concept.¹ In *The Phenomenology of the Social World*, Schutz explored how knowledge helps individuals coordinate their actions and plans, framing this exploration in the quest for intersubjective understanding. Shared meaning across individuals plays an important role in this understanding. Schutz contended that humans use ideal types daily and that those ideal types contain our conscious and unconscious knowledge, past and current. This knowledge combines with our perceptions to enable us to form expectations about the motives, plans, and actions of others (Knudsen 2004, 48). This understanding of the separate existence and perception of "the other" led Schutz to argue that meaning is subjective and therefore differs for each individual ([1932] 1967, 138). Furthermore, Schutz argued that individual perception of the surrounding environment and of events and actions, not to mention perception of the motives of other agents, is fragmentary and incomplete. Subjective meaning and fragmentary perception combine to create private local knowledge.

During the same period as Schutz's investigation of subjective and fragmentary knowledge, Hayek and Mises were embroiled in the socialist calculation debate. Hayek tended to emphasize more the ideas associated with the knowledge problem, building implicitly on Schutz's work, while Mises took a more computational approach that was still focused on the information available to agents to enable them to perform economic calculation. More than a mathematical exercise, economic calculation encompasses an evaluation of the subjective perceptions and trade-offs of current and future decisions made in a dynamic, complex, nondeterministic environment. Economic calculation enables the connection of means and ends and the assessment of value in purposeful human action. Mises tended to characterize the problem with socialism as an economic calculation problem, while Hayek tended to view the main problem underlying socialist calculation as being that of aggregating and acting on dispersed private knowledge, but these arguments complement each other through their shared emphasis on the irreplaceable role of decentralized money prices and market processes in a large, complex system. Mises described money prices as "aids to the mind" that facilitate economic decision-making in a complex economy ([1920] 1990, 12), while also arguing that a complex economy is characterized in part by a division of knowledge ([1922] 1981, 101). The absence of prices in a socialist system would mean the absence of the information contained in prices enabling agents to make choices and coordinate plans (Yeager 1994; see also Horwitz 2004 and Ebeling 2008). Economic calculation plays a coordinating role in dynamic social systems, and decentralized decisions facilitated by prices are indispensable in enabling that coordination to occur by providing a way to access dispersed, private knowledge.

¹ For an analysis of the use of ideal type methodology in economics, see Koppl (1994).

Thus, we can distinguish between the knowledge problem and the computation problem as different but related aspects of the critique of centralized economic planning (Lavoie 1986, 5). The knowledge problem argument that Hayek developed in the socialist calculation debate was primarily the complexity knowledge problem, focusing on the impossibility of accessing and aggregating dispersed private knowledge in the absence of prices and market processes. In the debate, however, Hayek was already formulating the contextual knowledge problem argument by arguing that much of the knowledge relevant to decision-making is inarticulate (Hayek 1935, 210).

Hayek's essay "Economics and Knowledge" (1937) explores some of the same problems of coordination in the presence of dispersed and local knowledge that Schutz explored and complements the arguments against central economic planning that Mises laid out in the socialist calculation debate. He does so in the context of examining the information assumptions associated with the economic concept of equilibrium. Information (or data), knowledge, and foresight undergird the equilibrium state, a state in which agents have coordinated, mutually compatible plans from which no agent deviates. What knowledge is necessary for achieving equilibrium, and how do agents acquire it? Analyzing the epistemic conditions for equilibrium, Hayek starts to connect the ideas of Schutz, Mises, and others with his own to develop the knowledge problem critique of neoclassical economic theory.

Hayek begins this argument by characterizing data, or a stock of information, as observable and knowable facts given to an individual. Neoclassical equilibrium models assume full availability of such data, but how is that possible when the actions of one person provide the data for other people and any change in the relevant data will disrupt equilibrium because others will change their plans, which changes the data for others, and so on (Hayek 1937, 36–38)? Moreover, equilibrium is time-dependent because agents will adjust their expectations of the actions of others, in addition to adjusting their own actions, as they observe and learn from experience. The plans, actions, and expectations of agents are interdependent, and changes in those variables for one agent can lead to a change in information and expectations in others; this interdependence is one hallmark of a complex system. Thus, a defining characteristic of equilibrium is that agents have perfect foresight—their expectations are all realized, contributing to their lack of deviation from their plans—but we should not make perfect foresight assumptions in models because perfect foresight is unlikely to exist in disequilibrium (42).

His critique continues with the "common knowledge" assumption that even if agents are not omniscient, they possess the knowledge relevant to their individual and joint economic decision-making. Theory that relies on this assumption does not create any understanding of where and how agents acquire or communicate the relevant knowledge that enables them to achieve equilibrium (Hayek 1937, 46).² Through this critique, Hayek begins to distinguish between information and knowledge.

² Morgenstern was also making related critiques of the common knowledge and perfect foresight assumptions underlying models of perfect competition; his critiques provided a foundation for the development of game theory in economic analysis.

In the standard full-information assumptions underlying the neoclassical equilibrium model, the form that necessary knowledge takes is straightforward: an individual agent knows his or her preferences or cost of production and also full common knowledge across agents about market prices. Hayek's counter to this argument is twofold. First, the knowledge relevant to decision-making goes beyond market prices; it also includes knowledge such as individual skills and alertness to or awareness of profit opportunities. Second, the knowledge relevant to decision-making is dispersed among agents in the economy (he credits Mises with the "division of knowledge" concept), and yet a market economy enables the "spontaneous interaction" of these agents with diffuse private knowledge to bring about an outcome "in which prices correspond to costs" (Hayek 1937, 50–51). Analyzing the importance of the dispersion of knowledge marked the beginning of Hayek's extensive work on the knowledge problem. "Economics and Knowledge" enabled Hayek to explore the crucial role of learning processes in the concept of equilibrium itself (Knudsen 2004, 62).

This background creates a context for the seminal arguments in "The Use of Knowledge in Society" (Hayek 1945), which refined the ideas developed in "Economics and Knowledge" (Hayek 1937) and the socialist calculation debate to address the fundamental role that the price system plays in aggregating and communicating dispersed private knowledge among the autonomous individual agents who interact, usually anonymously, through market processes. Here Hayek departs from the equilibrium framework of "Economics and Knowledge" and develops the role of prices as knowledge surrogates (Horwitz 2004, 314). This departure from the equilibrium framework marks a significant turn in Hayek's work in general, including his analysis of knowledge (Thomsen 1992).

Hayek characterized the fundamental economic problem not as the static allocation of scarce resources among uses by omniscient agents but rather as the coordination of actions and plans among dispersed agents with diffuse private knowledge. In his statement that "the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess" (Hayek 1945, 519), Hayek draws on the earlier arguments of the socialist calculation debate and of his (1937) work. The "man on the spot" (1945, 524) has subjective, private knowledge of "the particular circumstances of time and place" (522), and that knowledge is among the decision-relevant data that cannot be aggregated except through a decentralized system of prices and a market process of exchange to determine those prices. Prices economize on the communication and interpretation of knowledge among dispersed agents.

How do individuals learn the plans of others? How do they learn when they are wrong and take action accordingly? Prices and market processes provide feedback channels. Feedback loops, learning, adaptation to a changing environment and changing actions and plans of others, interdependence of agents and their actions in a complex system, and how prices and markets serve as feedback loops making a complex system adaptive are all important implications of Hayek's argument. Prices provide profit opportunities and realized profits, and those realized profits serve as feedback that can spur

the discovery of new products, services, business models, or other ways to create value through economic activity. Alert entrepreneurs see these opportunities, learn from observed and realized feedback, and adapt their plans accordingly. Prices enable “error detection and correction within the market” (Boettke 1998, 135). Markets are processes for social learning and provide feedback channels for entrepreneurial alertness.

Note that Hayek’s argument here emphasizes the complexity knowledge problem. Knowledge is dispersed, subjective, and private, and capturing that knowledge to enable plan coordination requires a decentralized system of prices generated in a market process. However, as Horwitz (2004) noted (and as cited above), prices cannot convey full knowledge among individuals but instead communicate the consequences of the realized actions and interactions of many agents. For that reason, we should think of prices not as containing full knowledge but as knowledge surrogates that aggregate the knowledge reflected in individual actions. Full knowledge is unrealistic and not achievable by any person or group of people.

These ideas converge in Hayek’s *The Sensory Order* (1952), which provides a theoretical psychological framework for analyzing the context in which individuals actually make decisions. Hayek constructed a theory of mind in which the consciousness that we use to process, understand, and interact with the world around us is itself an emergent or unplanned abstract classification system. The mind creates distinctions and evolved because classifications that do not connect action to physical reality well enough for an individual to thrive will not survive (Horwitz 2000, 25). Individuals make decisions based on perception, which can be distinct and subjective because of the particulars of individual experience but which also has consistency across people because of the evolutionary process.³

Furthermore, the human mind has cognitive limitations, because in its entirety, the human mind cannot be comprehended fully by the human mind; an individual cannot grasp all of the relevant factual, institutional, and cognitive knowledge for decision-making because of the inescapable embeddedness of the human mind in the system. Hayek reaches this conclusion because he conceives of the mind as a self-organizing, emergent order; through evolutionary processes involving both the brain’s physical structure and the cultural and empirical experiences of individuals, the mind’s capacity to classify and distinguish emerges, beyond the conscious control of any one person. This theory of mind has significant implications for the definition of knowledge and the use of knowledge: “What this amounts to is that all the ‘knowledge’ of the external world which such an organism possesses consists in the action patterns which the stimuli tend to evoke, or, with special reference to the human mind, that what we call knowledge is primarily a system of rules of action assisted and modified by rules indicating equivalences or differences or various combinations of stimuli” (Hayek 1969, 41). The mind

³ These questions of perception and knowledge have their roots in David Hume, to the extent that Hayek’s theory of mind relies on the evolution of the mind and its distinctions via the interaction of biology and experience.

categorizes information and inputs (stimuli) and uses perception in the process, resulting in knowledge.

This theory of the mind as an emergent classification system complements the subjectivist approach to both value and knowledge and thus provides a scientific underpinning of the phenomenon of dispersed, private, subjective knowledge. It also resonates with the subjectivity and perception themes that Schutz had raised two decades earlier. Hayek's epistemological theory in *The Sensory Order* reinforces the argument that knowledge is different from data/facts, is not given, is not objective, and includes not just preference- and cost-related knowledge but also institutional knowledge—the rules by which we interact and exchange in society. These rules, both informal and formal, are grounded in custom as the transmitter of rules that have proven effective, or robust, over time.

INFORMATION AND KNOWLEDGE IN MODERN ECONOMICS

During the twentieth century, many economists conflated knowledge and information, although knowledge and information are not the same thing. While paying attention to and approaching the problems of the complexity knowledge problem in their models of decentralized mechanisms, the game theory and mechanism design literatures ignore the contextual knowledge problem (Boettke 1998, 150). Theorists typically make strong assumptions regarding information, starting with the assumption that information incompleteness is a stochastic problem and that information has a known underlying probability distribution. While the distinction between risk and uncertainty is typically associated with Frank Knight, Austrian economists have used this distinction to point at a significant difference between this definition of *information* and *knowledge*, over which there can be no known probability distribution *ex ante*, in either the complexity sense or the contextual sense of knowledge. Moreover, these models often rely on the assumption that complete information is available but at a cost: “complete information is available, but agents are imperfectly informed and have to engage in a deliberate process of gathering the information that is relevant to their decision-making” (Boettke 2002, 265). The related literature on search theory relies on similar assumptions and characterizes agents as Bayesian updaters of their priors as they acquire more information. This treatment of information is consistent with the complexity/coordination knowledge problem analyzed in Hayek (1945), but it inaccurately treats information aggregation mechanistically, in addition to ignoring or assuming away the contextual knowledge problem.⁴

⁴ For example, Stigler (1961) wrote one of the first papers in the information literature, and his mechanistic treatment of information falls prey to this criticism. While a seminal work in the development of information economics, it does not engage or address any of the knowledge problem arguments that Hayek had raised in the preceding twenty-five years.

Despite such developments, modern information theory (encompassing game theory and mechanism design) has Austrian roots in Oskar Morgenstern (Foss 2000). Morgenstern was a key member of the reading group that Mises held in Vienna between 1922 and 1934, through which he developed and shared ideas with Hayek, Schutz, and others. A critic of the simplistic information assumptions of neoclassical economic theory, Morgenstern brought a process approach to understanding the interdependence and strategic interaction of agents in a social system, including their beliefs about one another that enabled them to form expectations. Through his pioneering collaboration with John von Neumann to develop game theory and apply it to economic questions, Morgenstern challenged the fundamental assumptions about information and knowledge in economic theory and contributed to a fundamental change in the assumptions and the methodology of economic theory.

Morgenstern ([1935] 1976) analyzed the perfect foresight assumptions of equilibrium economic theory when applied across several agents in an economy and how they might simultaneously all have perfect foresight. In a result that would be important later in game theory, Morgenstern argued that the strategic interaction of multiple agents made it difficult to justify the assumption of perfect foresight for all agents. The self-reference problem meant that the simultaneous perfect foresight assumption made equilibrium a degenerate outcome of the model (Knudsen 2004, 63). He also argued that this problem would make the theory of perfect competition conceptually problematic; Hayek would reach the same conclusion two years later in “Economics and Knowledge.” Both Hayek and Morgenstern argued that maximization is only a well-defined concept in equilibrium, and when agents are not in equilibrium, the model could not say anything about how they make choices or about the process by which they could converge to an equilibrium. One consequence of this exploration of the conceptual problems of knowledge and foresight in perfect competition was that both Hayek and Morgenstern contributed to Morgenstern’s subsequent development with Neumann of strategic interaction, game theory, and individual-choice-interdependent, strategic environments. Schotter (1992) and Shubik (1992) both recognize Morgenstern’s original contribution to game theory arising from his focus on the paradox of perfect foresight in equilibrium theory (Knudsen 2004, 65).

Herbert Simon’s (1982) work on bounded rationality reflects the influence of both Hayek’s knowledge problem ideas and modern information theory. Simon bridged economics, decision science, information theory, complex systems, and psychology in developing his theory of bounded rationality. He took the inescapable incompleteness of knowledge at both a mechanical and an epistemic level and concluded that individuals generally make the best decisions they can, given the physical and cognitive limitations people possess. The shared influence of Hayek’s work on the knowledge problem, modern information theory, and Simon’s bounded rationality synthesis also shows up in Vernon Smith’s (2009) concept of ecological rationality.

A related area of inquiry that builds on these different strands is psychologist Gerd Gigerenzer’s (1999) analyses of the “fast and furious” heuristics and rules of thumb that individuals use to filter, categorize, and act on their simultaneous flood of information

and lack of knowledge (see also Gigerenzer and Goldstein 1996). These heuristics are grounded in bounded rationality and, whether consciously or unconsciously, develop and are transmitted over time and are context-dependent. This idea reinforces Hayek's later arguments for emergent social institutions, often based on informal norms and customs, as a historical information repository that "made institutions" cannot replicate; institutions serve as a sort of social heuristic for the intertemporal transmission of social knowledge.

THE CONTEXTUAL KNOWLEDGE PROBLEM

Thus, as the complexity knowledge problem filtered into Austrian economics, information theory, and ultimately the neoclassical economics synthesis, the contextual argument continued to develop that not all relevant knowledge is conscious, articulate, or given. Here I define contextual knowledge as including tacit knowledge (knowledge relevant in specific contexts that we do not know consciously that we know or how we acquired the knowledge), inarticulate knowledge (unexpressed or unspoken knowledge underlying an action or decision), and emergent knowledge that only exists in the specific context of a purposeful action or interaction. Hayek elaborates on the contextual knowledge problem in "Competition as a Discovery Procedure" ([1968] 1978), although traces of it show up notably in "The Competitive 'Solution'" ([1940] 1948), "The Use of Knowledge in Society" (1945), and *The Sensory Order* (1952), among other works. Hayek's earlier work on diffuse private knowledge and critiques of the full information assumptions of neoclassical equilibrium models set the stage for extending the analysis to include contextual knowledge in decision-making and economic calculation. *The Sensory Order* provided a theoretical framework for the psychological and cognitive foundations of contextual knowledge.

The contextual knowledge problem incorporates the idea of knowledge generation *within* the market process and thus presents a substantial challenge to rationalist neoclassical treatments of information. Some of the knowledge relevant to decision-making and economic calculation does not exist independent of the market context. Knowledge is, therefore, in part a function of individual perception, again reflecting the earlier concepts of Schutz and the psychological framework from *The Sensory Order*. Boettke (1998) summarizes the argument that some knowledge needed for economic calculation exists only within the actual market context:

[T]he benefits of competitive markets are tied to the existence of markets and *cannot* be obtained independent of that context. . . . The *knowledge* argument is a contextual argument. Hayek's argument is not limited to the complexity issue of how various scattered bits and pieces of information held privately can be summarized in a form which is objectively useful for others so that economic actors can coordinate their plans. . . . In addition to the complexity argument that most scholars read in Hayek,

there is an argument—as we have seen—that the knowledge required for economic calculation is available only within the market process itself. Outside of that context this knowledge does not exist. And, it is precisely this contextual knowledge of the market which enables economic actors to select out from among the numerous array of technologically feasible production projects those which are economically viable—in other words to engage in rational economic calculation. (145; emphasis in original)

Thus, such knowledge is itself emergent and is endogenously created within the market process; this is the primary sense in which the market is a discovery procedure.

The contextual nature of knowledge also contributes to understanding feedback effects in social systems. For example, contextual knowledge means that individuals and the patterns that emerge from their aggregate interactions in social systems are prone to amplification through positive feedback, such as riots, bubbles, and bank panics (and more innocuous effects, such as doing the wave at sporting events or participating in a standing ovation). But contextual knowledge also helps us understand the dampening, or equilibrating, negative feedback effects in markets that take the form of entrepreneurial alertness (Kirzner 1997). Exploring the intersection of the Austrian concept of contextual knowledge and models of feedback effects in complex systems is a fruitful area for future research in a variety of applications.

Later scholars have also synthesized and further developed both the complexity and contextual knowledge problems. In *Knowledge and Decisions* ([1980]1996), Thomas Sowell develops these ideas and uses them to analyze the social processes and institutions to aggregate fragmentary knowledge, coordinate decisions across individuals possessing this fragmentary knowledge, and generate beneficial outcomes and enable a complex society to emerge and function. The unifying theme of *Knowledge and Decisions* is that

the specific mechanics of decision-making processes and institutions determine what kinds of knowledge can be brought to bear and with what effectiveness. In a world where people are preoccupied with arguing about what decisions should be made on a sweeping range of issues, this book argues that the most fundamental question is not what decision to make but who is to make it—through what processes and under what incentives and constraints, and with what feedback mechanisms to correct the decision if it proves to be wrong. (Sowell [1980] 1996, xxii)

Sowell uses the reality of the knowledge problem as a starting point to analyze the institutions humans use to make collective decisions. He emphasizes the evolutionary nature of complex social systems, in which much of the rationality guiding individual decisions is embedded in the inarticulate knowledge contained in such social processes.

Don Lavoie (1986) provides one of the seminal works in the development of the knowledge problem with his thorough analysis of the inarticulate nature of knowledge. Not only does he give the knowledge problem its name in this work (1986, 6), but he also expands the contextual knowledge problem argument in particular by

analyzing the pervasiveness of inarticulate knowledge and its implications. Consider, as Lavoie does, the problem of riding a bicycle: most people ride bicycles even without knowing the physics underlying how to maintain balance on a bicycle, without solving the equations for the bicycling equilibrium. Knowing how to ride a bike is an example of inarticulate knowledge, the difference between “knowing that” if I pedal fast enough the wheels will turn to maintain balance and “knowing how” the physics works (1). Similarly, inarticulate knowledge informs economic decision-making, and that knowledge emerges from our actions and interactions in the process of exchange. An important implication of the pervasiveness of inarticulate knowledge is that an *ex ante*, nonmarket, decentralized mechanism cannot replicate either the efficiency or the knowledge-creating or knowledge-revealing effects of prices and market processes. Decentralized market processes and price mechanisms can elicit and make use of inarticulate knowledge where other institutions cannot. Lavoie also includes in inarticulate knowledge the inarticulate meaning attached to prices, concluding that this inarticulate, subjective, personal meaning is impossible to create otherwise or, therefore, to aggregate through some other nonmarket means (16). No one knows the meaning that a person attaches to an item, a concept, or an action other than that individual; that said, though, that person may not even be able to articulate that meaning or why it exists in a way that is comprehensible to someone else. Yet that person can still act purposefully on that inarticulate meaning in a market context. This insight incorporates a Schutsonian theme: meaning itself, with subjectivity and with fragmentary personal perception, is also a part of knowledge. Interpretation and judgment create knowledge (Boettke 2002).

IMPLICATIONS FOR INSTITUTIONAL DESIGN

The knowledge problem is particularly relevant in political economy, or the comparative analysis of economic and social institutions and their performance. Some of the most important implications of the knowledge problem arise in the area of institutional design. Economics is the study of human action and decisions, and all such activity takes place within an institutional context; the informal and formal institutions that structure individual incentives do shape decisions and thus ultimately affect outcomes. Consider a general model of human action and decision-making, in which the important determinants of an individual's actions and interactions are his or her preferences, the environment, and the institutional framework. Institutions interact with preferences and the environment to determine individual actions and interactions with others. Thus, economists can evaluate the relationship of institutions to outcomes, taking into account the incentives they generate and the features of the environment in which the institutions operate. Furthermore, using the Austrian conception that the fundamental economic problem is the coordination of actions and plans among heterogeneous agents with dispersed, private, contextual knowledge, we can frame the institutional question as one of

evaluating the emergence and the deliberate design of institutions that maximize social cooperation (Horwitz 2000).

Institutions often emerge out of history, experience, and trial-and-error experimentation, and in fact, formal legal institutions have often been codifications of informal norms and emergent informal legal systems, some of which had existed for centuries. In this sense, we can think of, for example, the English common law as an emergent legal order, or an organic, grown legal order grounded in basic principles of property rights, commutative justice to defend negatively defined rights, rights of contract, and consent (Hayek 1960). The long evolution of precedent and the roles of judges in interpreting the common law provide feedback channels that enable this legal institution to change over time, to adapt to changes in the economic, social, and physical environment and changes in preferences. The experiences and information flows that inform this evolution feed into the legal system in a bottom-up manner, through individual interactions and experimentation.

The knowledge problem is a fundamental reason for the robustness and longevity of the English common law, in the sense that robust institutions “generate prosperity in less than ideal conditions” (Leeson and Subrick 2006, 107). The common law’s emphasis on enforcing basic, universal principles of physical liberty, property rights, contract, and consent has worked to promote prosperity even in the presence of other limitations and obstacles to economic growth, and its feedback channels for incremental modification in a changing environment enable trial-and-error experimentation in economic activity. This legal institution is compatible with both the complexity and the contextual aspects of the knowledge problem. The common law does not require aggregation of diffuse private knowledge in order for a community to meet and enforce its principles, and its grounding in these basic principles enables individuals to prosper from the exercise of their division of knowledge through mutually beneficial exchange. It also does not restrict the ability of individuals to act on their contextual knowledge, as long as those actions do not harm the rights of others with respect to life, property, contract, and consent. In the course of creating and exploiting such opportunities, these individuals actually create a more complex economic and social order as they innovate and take entrepreneurial actions to create new value propositions; our modern society is an example of this general pattern in economic history.

Contrast this concept of emergent institutions and the example of the English common law with the idea of “made” institutions (here the contrast is between *made* and *grown*). Such deliberately designed institutions typically are created through legislative and administrative procedures and are imposed in a top-down fashion to achieve a specific objective. Economic regulation frequently takes this form, whether at the local level (e.g., zoning regulations) or at the national level (e.g., regulations on the business activity of the financial industry).

These made institutions do not always facilitate outcomes consistent with taking into account the knowledge problem and thus also do not necessarily maximize social cooperation. They often limit the ways in which individuals could create mutual benefit by making use of diffuse private knowledge. A concrete example of this problem is the

regulation of retail electricity prices, which for most customers for more than a century in the United States have been fixed to reflect the average cost per unit (Kiesling 2008). This unvarying regulated price (and the operation of the retail provider as a government-granted monopoly) precludes any different pricing over time to appeal to consumers whose preferences vary over the course of the day, week, month, or season. Such dynamic pricing could benefit both producer and consumer and could enable signaling of the relative value of electricity in that hour as a knowledge surrogate for those interested in consuming electricity in that hour. The top-down imposition of this price control stifles the exercise of private knowledge and the creation of contextual knowledge, resulting in an inferior outcome to the extent that consumer preferences deviate from the average-cost-based regulated price, and the regulated monopoly status means that the firm never faces a market test of its pricing decisions. Any instance of price controls falls prey to this knowledge problem critique, because price controls truncate both the communication of dispersed knowledge and the creation of contextual knowledge.

Seeing the negative consequences of failing to allow for the knowledge problem can be problematic, though, because it requires comparing the actual outcome of the made institution with the next feasible institutional alternative that would allow for more decentralized coordination. This comparison is often counterfactual, unless, for example, another state or country has this institutional alternative and data available for a comparative institutional analysis. Other research methodologies can illuminate this problem, such as experimental economics and agent-based modeling. Both of these approaches require simplification and paring down of the environment and the institution to their most salient features (and have other characteristics, good and bad, that go beyond the scope of this chapter), but they can be used effectively for an institutional analysis that incorporates the knowledge problem.

The institutional and political economy implications of the knowledge problem are significant, because the knowledge problem strikes at the core of some of the most essential assumptions underlying government action and regulation. At some level, arguments for government intervention and the associated theoretical models and institutional designs all rely on the presumption of the existence, knowability, and stability of an optimal outcome. The complexity knowledge problem suggests that optimal outcomes are not knowable *ex ante*, while the contextual knowledge problem means the stability of the optimality of an outcome is very context-dependent and that if such an outcome does exist, its existence may be fleeting and ephemeral. As Boettke et al. (2005) observed in their discussion of the relevance of the knowledge problem to comparative institutional analysis:

The principles of optimality within a market economy are the outcome of a competitive process, not merely a formal mathematical rule that is an assumption going into that process. Firms seek to maximize profits and in competition with other firms stumble to marginal cost pricing and producing at the level that minimizes average costs. Pricing equal to marginal cost does mean that the full opportunity cost of

resource use is being taken into account and minimizing average costs does translate into the deployment of all least cost technologies, but the important point Mises and Hayek were attempting to make is that these optimality conditions emerge out of the competitive market process. (285)

The institutional context will affect the knowledge and the actions available to individuals who are trying to coordinate their actions for mutual gain. Thus, a regulatory plan or institutional design based on theoretical models that ignore the knowledge problem is grounded in unrealistic assumptions and is therefore prone to unintended consequences and an inability to achieve the desired, postulated optimal outcome.

Neoclassical public utility regulation provides a stark example of this phenomenon. The underlying theoretical model stipulates a static cost function with economies of scale over the relevant range of (static) demand and proposes an institutional design in which regulators control the rate of return the regulated firm earns on its assets such that on average, the regulated retail price equals average cost and the regulated firm earns zero economic profit. While several scholars in industrial organization have formulated models incorporating the information asymmetry with respect to the firm's costs (see, for example, the literature reviewed in Laffont and Tirole 1993), these models continue to embody the assumptions of static, knowable demand and costs. These assumptions increase the tractability of a formal model, at a cost of forgoing any understanding of the effects of the knowledge problem on the actual outcomes of particular institutional designs based on such formal models. Boettke et al. (2005) provide a thorough discussion of development economics as another policy example prone to these criticisms.

Examples like these illustrate the importance of the knowledge problem both as an unavoidable trait of humans and social systems and as a performance metric in the field of robust political economy. As mentioned above, robustness is a measure of how well an institution performs in enabling prosperity even in the least favorable situations: "For instance, it is not so obvious that in an economy of less than perfectly rational, perfectly informed individuals where prices are sticky and informational asymmetries persist that markets will prove efficient and general equilibrium will obtain. The hard case is hard because in order to demonstrate the desirability of a particular system under worst-case scenarios, the system must be robust" (Boettke and Leeson 2004, 100).

Robust social institutions take into account the cognitive, psychological, and strategic realities of being human and trying to live together in civil society, rather than being based on some mythical, hypothetical agents who are either entirely Cartesian-rational, entirely Hobbesian-rapacious, or possessing full foresight.

Robust political economy uses two main criteria to evaluate institutions: simply put, the absence of both omniscience and benevolence. Robust political economy uses the knowledge problem as an essential component of defining robustness and evaluating different institutional designs and their performance. Such an analysis requires moving away from the restrictive, unrealistic assumptions underlying formal theoretical models and toward an analytical framework that recognizes the knowledge problem, takes into

account human imperfection and bounded rationality, and acknowledges the range of motives facing individuals as economic actors and bureaucrats. Part of this framework includes individual beliefs and the extent of shared meaning, because without understanding social meaning, it is difficult to understand incentives and how people act on them (Boettke et al. 2005, 290). In this sense, robust political economy and its treatment of knowledge tie directly back to the Schutzhian questions of perception and social meaning in the early twentieth century.

Benevolence captures the set of ideas, incentives, and models arising from public choice theory. If we relax the assumption that individuals are benevolent and well intentioned in their roles as policy makers and bureaucrats and instead assume that they will make institutional decisions based on their own self-interest, how well does the institution made in that process perform in facilitating prosperity? More realistically, humans have diverse motivations, ranging from material self-interest to benevolence and individual disinterestedness, and a robust political economy analysis examines how an institution performs under the worst-case assumption of policy makers and bureaucrats having material self-interest motivations. Following Hume and James Buchanan, we could call this the “men as knaves” criterion for evaluating institutions (Pennington 2011, 5).

Omniscience (or the lack thereof) reflects the role of the knowledge problem in institutional analysis. Taking into account the knowledge problem, what are institutional traits that enable heterogeneous self-interested individuals, for whom self-interest usually takes many different forms, to live together and to thrive in civil society? The knowledge problem means that the ultimate, specific individual consequences of a particular institution, along with the wider social or system-level consequences, will be unknown. Both complexity and context point to the inability to predict the specific consequences of an institution, and indeed the creation of new contextual knowledge is part of the reason for the complexity of social systems and the nondeterministic nature of social system outcomes. Thus, “[r]obust institutions should therefore allow people to adapt to circumstances and conditions of which they are not directly aware, and under conditions of ‘bounded rationality’ must enable them to learn from mistakes and to improve the quality of their decisions over time” (Pennington 2011, 3). Robust social institutions are those that fare better in conditions of imperfect and incomplete knowledge and that allow the processes of experimentation, adaptation, and evolution to occur that are essential for error correction. These processes and the resulting error correction are crucial foundations for facilitating and aligning individual and social prosperity.

One substantial insight of robust political economy is that given the inescapable reality of the knowledge problem, institutions that enable adaptation by individuals, that allow for experimentation, and that can themselves adapt to unknown and changing conditions are more likely to be robust and generate superior outcomes (Pennington 2011, 4–5). In dynamic, complex social systems, change is ubiquitous and pervasive; agents within these systems change their behavior in response to changes in their own perceptions of preferences and opportunity costs, to changes in the actions of others,

and changes in the rules that structure these interactions and shape their incentives and behavior. Because social systems are complex, the outcomes of these interactions are nondeterministic, so designing rules *ex ante* that will enable perfect plan coordination and avoid processes such as rent dissipation or contract renegotiation is difficult, if not impossible. Indeed, North (2005) contends that the nonergodic nature of dynamic, complex social systems means that designed rules (made institutions) are almost always out of date, because they are designed to address issues and incentives at a particular time and context. The constantly changing world changes that context and at the margin changes the relative importance of different issues and the relative weight of incentives in shaping behavior.

Experimentation enables social learning in these complex social systems in which both economic outcomes and how specific institutions will function are unknown (Kiesling 2010). Only by experimenting with different institutions or by testing institutions in economic experiments that capture the salient features of the real-world environment can we learn the effects of rules on behavior, resource allocation, and other social phenomena (such as social cohesion). The rules embedded in different institutions change the interactions of individuals in complex social systems, thereby changing outcomes, often in unpredictable and nondeterministic ways.

The knowledge problem's centrality in robust political economy points to another dimension to explore in institutional analysis: complexity science and its application in economics and the analysis of social systems. Complexity economics draws on the extensive, interdisciplinary literature on complex adaptive systems and frames economic questions explicitly in terms of the dynamics of human action and interaction, over space and time.⁵ As Tesfatsion (2001) observes:

Decentralized market economies are complex adaptive systems, consisting of large numbers of buyers and sellers involved in massively parallel local interactions. These local interactions give rise to macroeconomic regularities such as shared market protocols and behavioral norms that in turn feed back into the determination of local interactions. The result is a complicated dynamic system of recurrent causal chains connecting individual behaviors, interaction networks, and social welfare outcomes. (1)

Markets are complex adaptive systems that involve large numbers of distributed actors and rules, or institutions, governing their interactions. A complex adaptive system has a large number of interacting heterogeneous agents. These agents react to the actions of other agents and to changes in the environment, and they are autonomous, so control and decision-making are decentralized and distributed in a complex adaptive system. Through their interactions, the agents in the system adapt to the changes that they themselves help to bring about through their independent decisions, and the

⁵ This discussion draws on the more extensive treatment in Kiesling (2008), chap. 3.

effects these decentralized decisions have on individual and system-level outcomes provide feedback channels for learning, adaptation, and evolution.⁶

This distributed learning and decision-making process leads to potentially unanticipated changes in the environment, but a principal defining characteristic of a complex adaptive system is that it is self-organizing, and that self-organization, or order, emerges from the interaction (i.e., is an emergent property). Complex systems are defined by their dynamic properties and the extent to which the interactions of agents are non-deterministic and are thus emergent phenomena (Metcalf 2010). Complex systems have the superficially contradictory combination of unpredictable specific outcomes with system-level patterns of self-organization and emergent order; this combination also features prominently in Austrian economics.

In the presence of knowledge constraints and cognitive limitations, such as sheer ignorance (Kirzner 1997) or bounded rationality (Simon 1982), market processes enable these agents to achieve their plans mutually. In the process of doing so, market processes generate and aggregate information that reduces uncertainty and ignorance; this information also enables agents to adapt by revising their plans and actions. In this analysis, we take diffuse, private, and tacit knowledge as given and focus on the role of economic, legal, and social institutions in aggregating that diffuse knowledge and enabling decentralized agents to coordinate their plans and actions.

Decentralized coordination occurs in market processes through prices. Prices allow for the decentralized coordination of plans among distributed, heterogeneous agents with private knowledge. Price signals act as feedback and coordination mechanisms in two distinct ways. First, in a market in equilibrium, the equilibrium price signals to individual agents what their decisions should be. In particular, price signals communicate to lower-value consumers and higher-cost producers that they are low-value and high-cost, respectively. Second, in a market in disequilibrium, price signals communicate information that results in agents making systematic changes to their bids and offers; these changes themselves enhance the degree of coordination via feedback mechanisms. Price signals are an information flow that may lead agents to revise their decisions, resulting in a higher degree of plan coordination.

More generally, the knowledge problem forms the basis for the existence of complexity in social systems, for the evolution of complex adaptive social systems, and for the discovery and design of rules and institutions that exploit that complexity to get better outcomes (and enable us to use our imperfections to our advantage). Markets and prices are the most obvious and pervasive example, but there are multitudes of others, many awaiting deeper examination using the ideas and tools described here.

⁶ For a thorough discussion of complexity economics, a critique of neoclassical economics, and an application of complexity economics to analyzing economic growth and business strategy, see Beinhocker (2006); see also Rosser (2009) and Holt, Colander, and Rosser (2010). For a primer on complexity science and complex adaptive systems, see Miller and Page (2007) and Mitchell (2009).

CONCLUSION

The development of the knowledge problem and its implications over the past century has enriched our understanding of the challenges of coordination and also of why systems for decentralized coordination tend to perform better in an environment with imperfect and incomplete knowledge. This research has also indicated the epistemic nature of the knowledge problem, beyond the mechanical search for information that is reflected in modern information theory. A research agenda incorporating the knowledge problem and synthesizing Austrian economics, robust political economy, and complexity science, using tools including experimental economics and agent-based modeling, will generate a deeper understanding of the processes and institutions through which human societies achieve coordination and social cooperation.

Knowledge is inherently imperfect, because it is dispersed, private, local, often tacit, frequently inarticulate, sometimes ephemeral, and usually contextual. Economic models based on assumptions of perfect knowledge thus do a poor job of capturing the informational and epistemological factors that are most relevant to both static and dynamic decision-making and economic calculation. Economic and social institutions designed deliberately based on those models are unlikely to perform well at generating prosperity, as research in robust political economy indicates and as Hayek (1974) suggested in his Nobel address:

If man is not to do more harm than good in his efforts to improve the social order, he will have to learn that in this, as in all other fields where essential complexity of an organized kind prevails, he cannot acquire the full knowledge which would make mastery of the events possible. He will therefore have to use what knowledge he can achieve, not to shape the results as the craftsman shapes his handiwork, but rather to cultivate a growth by providing the appropriate environment, in the manner in which the gardener does this for his plants. . . . The recognition of the insuperable limits to his knowledge ought indeed to teach the student of society a lesson of humility which should guard him against becoming an accomplice in men's fatal striving to control society—a striving which makes him not only a tyrant over his fellows, but which may well make him the destroyer of a civilization which no brain has designed but which has grown from the free efforts of millions of individuals.

REFERENCES

- Beinhocker, Eric. 2006. *The Origin of Wealth*. Cambridge, MA: Harvard Business Press.
- Boettke, Peter J. 1998. "Economic Calculation: The Austrian Contribution to Political Economy." *Advances in Austrian Economics* 5: 131–158.
- Boettke, Peter J. 2002. "Information and Knowledge: Austrian Economics in Search of Its Uniqueness." *Review of Austrian Economics* 15, no. 4: 263–274.

- Boettke, Peter J., Christopher J. Coyne, Peter Leeson, and Frederic Sautet. 2005. "The New Comparative Political Economy." *Review of Austrian Economics* 18: 281–304.
- Boettke, Peter J., and Peter Leeson. (2004) "Liberalism, Socialism, and Robust Political Economy." *Journal of Markets and Morality* 7(1): 99–111.
- Ebeling, Richard. 2008. "The Life and Works of Ludwig von Mises." *Independent Review* 13, no. 1: 99–109.
- Foss, Nicolai. (2000) "Austrian Economics and Game Theory: A Stocktaking and an Evaluation." *Review of Austrian Economics* 13: 41–58.
- Gigerenzer, Gerd. 1999. *Simple Heuristics That Make Us Smart*. Oxford: Oxford University Press.
- Gigerenzer, Gerd, and Daniel Goldstein. 1996. "Reasoning the Fast and Frugal Way: Models of Bounded Rationality." *Psychological Review* 103, no. 4: 650–669.
- Hayek, F. A., ed., 1935. "The Present State of the Debate." In *Collectivist Economic Planning*, 201–244. London: Routledge.
- Hayek, F. A. (1937) 1948. "Economics and Knowledge." In *Individualism and Economic Order*, 33–56. Chicago: University of Chicago Press.
- Hayek, F. A. (1940) 1948. "The Competitive 'Solution.'" In *Individualism and Economic Order*, 181–208. Chicago: University of Chicago Press.
- Hayek, F. A. 1945. "The Use of Knowledge in Society." *American Economic Review* 35: 519–530.
- Hayek, F. A. 1952. *The Sensory Order*. Chicago: University of Chicago Press.
- Hayek, F. A. 1960. *The Constitution of Liberty*. Chicago: University of Chicago Press.
- Hayek, F. A. (1968) 1978. "Competition as a Discovery Procedure." In *New Studies in Philosophy, Politics, Economics, and the History of Ideas*, 179–190. Chicago: University of Chicago Press.
- Hayek, F. A. (1969) 1978. "The Primacy of the Abstract." In *New Studies in Philosophy, Politics, Economics, and the History of Ideas*, 35–49. Chicago: University of Chicago Press.
- Hayek, F. A. 1974. "The Pretence of Knowledge." Nobel Prize lecture. Available at http://nobel-prize.org/nobel_prizes/economics/laureates/1974/hayek-lecture.html. Accessed February 25, 2011.
- Holt, Richard, David Colander, and Barkley Rosser. 2010. "The Complexity Era in Economics." Middlebury College Discussion Paper 10–01, Middlebury, VT. Available at sandcat.middlebury.edu/econ/repec/mdl/ancoec/1001.pdf. Accessed December 29, 2011.
- Horwitz, Steven. 2000. "From *The Sensory Order* to the Liberal Order: Hayek's Non-rationalist Liberalism." *Review of Austrian Economics* 13: 23–40.
- Horwitz, Steven. 2004. "Monetary Calculation and the Unintended Extended Order: The Misesian Microfoundations of the Hayekian Great Society." *Review of Austrian Economics* 17, no. 4: 307–321.
- Kiesling, Lynne. 2008. *Deregulation, Innovation and Market Liberalization: Electricity Regulation in a Continually Evolving Environment*. London: Routledge.
- Kiesling, Lynne. 2010. "The Knowledge Problem, Learning, and Regulation: How Regulation Affects Technological Change in the Electric Power Industry." *Studies in Emergent Order* 3: 149–171.
- Kirzner, Israel. 1997. "Entrepreneurial Discovery and the Competitive Market Process: An Austrian Approach." *Journal of Economic Literature* 35: 60–85.
- Knudsen, Christian. 2004. "Alfred Schutz, Austrian Economists and the Knowledge Problem." *Rationality and Society* 16: 45–89.
- Koppl, Roger. 1994. "Ideal Type Methodology in Economics." In *The Elgar Companion to Austrian Economics*, edited by Peter J. Boettke, 72–76. Aldershot, UK: Edward Elgar.

- Laffont, Jean-Jacques, and Jean Tirole. 1993. *A Theory of Incentives in Procurement and Regulation*. Cambridge, MA: MIT Press.
- Lavoie, Don. 1986. "The Market as a Procedure for Discovery and Conveyance of Inarticulate Knowledge." *Comparative Economic Studies* 28, no. 1: 1–19.
- Leeson, Peter, and Robert Subrick. 2006. "Robust Political Economy." *Review of Austrian Economics* 19: 107–111.
- Metcalf, J. Stanley. 2010. "Complexity and Emergence in Economics: The Road from Smith to Hayek (via Marshall and Schumpeter)." *History of Economic Ideas* 18, no. 2: 45–75.
- Miller, John, and Scott Page. 2007. *Complex Adaptive Systems*. Princeton, NJ: Princeton University Press.
- Mises, Ludwig von. (1920) 1990. *Economic Calculation in the Socialist Commonwealth*. Auburn, AL: Ludwig von Mises Institute.
- Mises, Ludwig von. (1922) 1981. *Socialism*. Indianapolis: Liberty Press.
- Mitchell, Melanie. 2009. *Complexity: A Guided Tour*. Oxford: Oxford University Press.
- Morgenstern, Oskar. (1935) 1976. "Perfect Foresight and Economic Equilibrium." In *Selected Economic Writings of Oskar Morgenstern*, edited by Andrew Schotter, translated by F. Knight, 169–183. New York: New York University Press.
- North, Douglass. 2005. *Understanding the Process of Economic Change*. Princeton, NJ: Princeton University Press.
- Pennington, Mark. 2011. *Robust Political Economy*. Cheltenham, UK: Edward Elgar.
- Polanyi, Michael. (1966) 2009. *The Tacit Dimension*. Chicago: University of Chicago Press.
- Rosser, Barkley, ed. 2009. *Handbook on Research in Complexity*. Aldershot, UK: Edward Elgar.
- Schotter, Andrew. 1992. "Oskar Morgenstern's Contribution to the Development of the Theory of Games." In *Toward a History of Game Theory*. Annual supplement to Vol. 24, *History of Political Economy*, edited by Roy Weintraub, 95–112. Durham, NC: Duke University Press.
- Schutz, Alfred. (1932) 1967. *The Phenomenology of the Social World*. Evanston, IL: Northwestern University Press.
- Shubik, Martin. 1992. "Game Theory at Princeton, 1949–1955: A Personal Reminiscence." In *Toward a History of Game Theory*. Annual supplement to Vol. 24, *History of Political Economy*, edited by Roy Weintraub, 151–164. Durham, NC: Duke University Press.
- Simon, Herbert. 1982. *Models of Bounded Rationality*, Vols. 1–2. Cambridge, MA: MIT Press.
- Smith, Vernon. 2009. *Rationality in Economics: Constructivist and Ecological Forms*. Cambridge: Cambridge University Press.
- Sowell, Thomas. (1980) 1996. *Knowledge and Decisions*. New York: Basic Books.
- Stigler, George. 1961. "The Economics of Information." *Journal of Political Economy* 69, no. 3: 213–225.
- Tesfatsion, Leigh. 2001. "Economic Agents and Markets as Emergent Phenomena." *Proceedings of the National Academies of Science* 99, supp. 3: 1–2.
- Thomsen, Esteban. 1992. *Prices and Knowledge: A Market Process Perspective*. London: Routledge.
- Yeager, Leland. 1994. "Mises and Hayek on Calculation and Knowledge." *Review of Austrian Economics* 7, no. 2: 93–109.