The Sciences of the Artificial

Third edition

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Economic Rationality: Adaptive Artifice

Because scarcity is a central fact of life—land, money, fuel, time, attention, and many other things are scarce—it is a task of rationality to allocate scarce things. Performing that task is the focal concern of economics.

Economics exhibits in purest form the artificial component in human behavior, in individual actors, business firms, markets, and the entire economy. The outer environment is defined by the behavior of other individuals, firms, markets, or economies. The inner environment is defined by an individual's, firm's, market's, or economy's goals and capabilities for rational, adaptive behavior. Economics illustrates well how outer and inner environments interact and, in particular, how an intelligent system's adjustment to its outer environment (its substantive rationality) is limited by its ability through knowledge and computation, to discover appropriate adaptive behavior (its procedural rationality).

The Economic Actor

In the textbook theory of the business firm, an "entrepreneur" aims at maximizing profit, and in such simple circumstances that the computational ability to find the maximum is not in question. A cost curve relates dollar expenditures to amount of product manufactured, and a revenue curve relates income to amount of product sold. The goal (maximizing the difference between income and expenditure) fully defines the firm's inner environment. The cost and revenue curves define the outer environment. Elementary calculus shows how to find the profit-maximizing

1. I am drawing the line between outer and inner environment not at the firm's boundary but at the skin of the entrepreneur, so that the factory is part of the external technology; the brain, perhaps assisted by computers, is the internal.
quantity by taking a derivative (rate at which profit changes with change in quantity) and setting it equal to zero.

Here are all the elements of an artificial system adapting to an outer environment, subject only to the goal defined by the inner environment. In contrast to a situation where the adaptation process is itself problematic, we can predict the system’s behavior without knowing how it actually computes the optimal output. We need consider only substantive rationality.2

We can interpret this bare-bones theory of the firm either positively (as describing how business firms behave) or normatively (as advising them how to maximize profits). It is widely taught in both senses in business schools and universities, just as if it described what goes on, or could go on, in the real world. Alas, the picture is far too simple to fit reality.

Procedural Rationality
The question of maximizing the difference between revenue and cost becomes interesting when, in more realistic circumstances, we ask how the firm actually goes about discovering that maximizing quantity. Cost accounting may estimate the approximate cost of producing any particular output, but how much can be sold at a specific price and how this amount varies with price (the elasticity of demand) usually can be guessed only roughly. When there is uncertainty (as there always is), prospects of profit must be balanced against risk, thereby changing profit maximization to the much more shadowy goal of maximizing a profit-vs.-risk “utility function” that is assumed to lurk somewhere in the recesses of the entrepreneur’s mind.

But in real life the business firm must also choose product quality and the assortment of products it will manufacture. It often has to invent and design some of these products. It must schedule the factory to produce a profitable combination of them and devise marketing procedures and structures to sell them. So we proceed step by step from the simple caricature of the firm depicted in the textbooks to the complexities of real firms in the real world of business. At each step toward realism, the problem

gradually changes from choosing the right course of action (substantive rationality) to finding a way of calculating, very approximately, where a good course of action lies (procedural rationality). With this shift, the theory of the firm becomes a theory of estimation under uncertainty and a theory of computation—decidedly non-trivial theories as the obscurities and complexities of information and computation increase.

Operations Research and Management Science
Today several branches of applied science assist the firm to achieve procedural rationality.1 One of them is operations research (OR); another is artificial intelligence (AI). OR provides algorithms for handling difficult multivariate decision problems, sometimes involving uncertainty. Linear programming, integer programming, queuing theory, and linear decision rules are examples of widely used OR procedures.

To permit computers to find optimal solutions with reasonable expenditures of effort when there are hundreds or thousands of variables, the powerful algorithms associated with OR impose a strong mathematical structure on the decision problem. Their power is bought at the cost of shaping and squeezing the real-world problem to fit their computational requirements: for example, replacing the real-world criterion function and constraints with linear approximations so that linear programming can be used. Of course the decision that is optimal for the simplified approximation will rarely be optimal in the real world, but experience shows that it will often be satisfactory.

The alternative methods provided by AI, most often in the form of heuristic search (selective search using rules of thumb), find decisions that are “good enough,” that satisfy. The AI models, like OR models, also only approximate the real world, but usually with much more accuracy and detail than the OR models can admit. They can do this because heuristic search can be carried out in a more complex and less well structured problem space than is required by OR maximizing tools. The price paid

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for working with the more realistic but less regular models is that AI methods generally find only satisfactory solutions, not optima. We must trade off satisficing in a nearly-realistic model (AI) against optimizing in a greatly simplified model (OR). Sometimes one will be preferred, sometimes the other.

AI methods can handle combinatorial problems (e.g., factory scheduling problems) that are beyond the capacities of OR methods, even with the largest computers. Heuristic methods provide an especially powerful problem-solving and decision-making tool for humans who are unassisted by any computer other than their own minds, hence must make radical simplifications to find even approximate solutions. AI methods also are not limited, as most OR methods are, to situations that can be expressed quantitatively. They extend to all situations that can be represented symbolically, that is, verbally, mathematically or diagrammatically.

OR and AI have been applied mainly to business decisions at the middle levels of management. A vast range of top management decisions (e.g., strategic decisions about investment, R&D, specialization and diversification, recruitment, development, and retention of managerial talent) are still mostly handled traditionally, that is, by experienced executives' exercise of judgment.

As we shall see in chapters 3 and 4, so-called "judgment" turns out to be mainly a non-numerical heuristic search that draws upon information stored in large expert memories. Today we have learned how to employ AI techniques in the form of so-called expert systems in a growing range of domains previously reserved for human expertise and judgment—for example, medical diagnosis and credit evaluation. Moreover, while classical OR tools could only choose among predefined alternatives, AI expert systems are now being extended to the generation of alternatives, that is, to problems of design. More will be said about these developments in chapters 5 and 6.

Satisficing and Aspiration Levels
What a person cannot do he or she will not do, no matter how strong the urge to do it. In the face of real-world complexity, the business firm turns to procedures that find good enough answers to questions whose best answers are unknowable. Because real-world optimization, with or without computers, is impossible, the real economic actor is in fact a satisficer, a person who accepts "good enough" alternatives, not because less is preferred to more but because there is no choice.

Many economists, Milton Friedman being perhaps the most vocal, have argued that: the gap between satisfactory and best is of no great importance, hence the unrealism of the assumption that the actors optimize does not matter; others, including myself, believe that it does matter, and matters a great deal.4 But reviewing this old argument would take me away from my main theme, which is to show how the behavior of an artificial system may be strongly influenced by the limits of its adaptive capacities—its knowledge and computational powers.

One requirement of optimization not shared by satisficing is that all alternatives must be measurable in terms of a common utility function. A large body of evidence shows that human choices are not consistent and transitive, is they would be if a utility function existed.5 But even in a satisficing theory we need some criteria of satisfaction. What realistic measures of human profit, pleasure, happiness and satisfaction can serve in place of the discredited utility function?

Research findings on the psychology of choice, indicate some properties a thermometer of satisfaction should have. First, unlike the utility function, it is not limited to positive values, but has a zero point (of minimal contempt). Above zero, various degrees of satisfaction are experienced, and below zero, various degrees of dissatisfaction. Second, if periodic readings are taken of people in relatively stable life circumstances, we only occasionally find temperatures very far from zero in either direction, and the divergent measurements tend to regress over time back toward the zero mark. Most people consistently register either slightly below zero (mild discontent) or a little above (moderate satisfaction).

To deal with these phenomena, psychology employs the concept of aspiration level. Aspirations have many dimensions: one can have aspirations for pleasant work, love, good food, travel, and many other things. For each dimension, expectations of the attainable define an aspiration level that is compared with the current level of achievement. If achievements exceed aspirations, satisfaction is recorded as positive; if aspirations exceed achievements, there is dissatisfaction. There is no simple mechanism for comparison between dimensions. In general a large gain along one dimension is required to compensate for a small loss along another—hence the system’s net satisfactions are history-dependent, and it is difficult for people to balance compensatory offsets.

Aspiration levels provide a computational mechanism for satisfying. An alternative satisfies if it meets aspirations along all dimensions. If no such alternative is found, search is undertaken for new alternatives. Meanwhile, aspirations along one or more dimensions drift down gradually until a satisfactory new alternative is found or some existing alternative satisfies. A theory of choice employing these mechanisms acknowledges the limits on human computation and fits our empirical observations of human decision making far better than the utility maximization theory.*

Markets and Organizations

Economics has been concerned less with individual consumers or business firms than with larger artificial systems: the economy and its major components, markets. Markets aim to coordinate the decisions and behavior of multitudes of economic actors—to guarantee that the quantity of brushes sprouts shipped to market bears some reasonable relation to the quantity that consumers will buy and eat, and that the price at which brushes sprouts can be sold bears a reasonable relation to the cost of producing them. Any society that is not a subsistence economy, but has substantial specialization and division of labor, needs mechanisms to perform this coordinative function.

Markets are only one, however, among the spectrum of mechanisms of coordination on which any society relies. For some purposes, central planning based on statistics provides the basis for coordinating behavior patterns. Highway planning, for example, relies on estimates of road usage that reflect statistically stable patterns of driving behavior. For other purposes, bargaining and negotiation may be used to coordinate individual behaviors, for instance, to secure wage agreements between employers and unions or to form legislative majorities. For still other coordinative functions, societies employ hierarchic organizations—business, governmental and educational—with lines of formal authority running from top to bottom and networks of communications laying through the structure. Finally, for making certain important decisions and for selecting persons to occupy positions of public authority, societies employ a wide variety of balloting procedures.

Although all of these coordinating techniques can be found somewhere in almost any society, their mix and applications vary tremendously from one nation or culture to another. We ordinarily describe capitalist societies as depending mostly on markets for coordination and socialist societies as depending mostly on hierarchic organizations and planning, but this is a gross oversimplification, for it ignores the uses of voting in democratic societies of either kind, and it ignores the great importance of large organizations in modern "market" societies.

The economic units in capitalist societies are mostly business firms, which are themselves hierarchic organizations, some of enormous size, that make almost negligible use of markets in their internal functioning. Roughly eighty percent of the human economic activity in the American economy, usually regarded as almost the epitome of a "market" economy, takes place in the internal environments of business and other organizations and not in the external, between-organization environments of markets. To avoid misunderstanding, it would be appropriate to call such...

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a society an organization—market economy; for in order to give an account of it we have to pay as much attention to organizations as to markets.

The Invisible Hand
In examining the processes of social coordination, economics has given top billing—sometimes almost exclusive billing—to the market mechanism. It is indeed a remarkable mechanism which under many circumstances can bring it about that the producing, consuming, buying and selling behaviors of enormous numbers of people, each responding only to personal selfish interests, allocate resources so as to clear markets—do in fact nearly balance the production with the consumption of brussels sprouts and all the other commodities the economy produces and uses.

Only relatively weak conditions need be satisfied to bring about such an equilibrium. Achieving it mainly requires that prices drop in the face of an excess supply, and that quantities produced decline when prices are lowered or when inventories mount. Any number of dynamic systems can be formulated that have these properties, and these systems will seek equilibrium and oscillate stably around it over a wide range of conditions.

There have been many recent laboratory experiments on market behavior, sometimes with human subjects, sometimes with computer programs as simulated subjects.8 Experimental markets in which the simulated traders are "stupid" sellers, knowing only a minimum price below which they should not sell, and "stupid" buyers, knowing only a maximum price above which they should not buy move toward equilibrium almost as rapidly as markets whose agents are rational in the classical sense.10

Markets and Optimality. These findings undermine the much stronger claims that are made for the price mechanism by contemporary neoclassical economics. Claims that it does more than merely clear markets require the strong assumptions of perfect competition and of maximization of profit or utility by the economic actors. With these assumptions, but not without them, the market equilibrium can be shown to be optimal in the sense that it could not be altered so as to make everyone simultaneously better off. These are the familiar propositions of Pareto optimality of competitive equilibrium that have been formalized so elegantly by Arrow, Debreu, Hurwicz, and others.11

The optimality theorems stretch credibility, so far as real-world markets are concerned, because they require substantive rationality of the kinds we found implausible in our examination of the theory of the firm. Markets populated by consumers and producers who satisfy instead of optimizing do not meet the conditions on which the theorems rest. But the experimental data on simulated markets show that market clearing, the only property of markets for which there is solid empirical evidence, can be achieved without the optimizing assumptions, hence also without claiming that markets do produce a Pareto optimum. As Samuel Johnson said of the dancing dog, "the marvel is not that it dances well, but that it dances at all"—the marvel is not that markets optimize (they don't) but that they often clear.

Order without a Planner. We have become accustomed to the idea that a natural system like the human body or an ecosystem regulates itself. This is in fact a favorite theme of the current discussion of complexity which we will take up in later chapters. We explain the regulation by feedback loops rather than a central planning and directing body. But somehow, untutored intuitions about self-regulation without central direction do not carry over to the artificial systems of human society. I retain vivid memories of the astonishment and disbelief expressed by the architecture students to whom I taught urban land economics many years ago when I pointed to medieval cities as marvelously patterned systems that had mostly just "grown" in response to myriads of individual human decisions. To my students a pattern implied a planner in whose mind it had been conceived and by whose hand it had been implemented. The idea that a city could acquire its pattern as naturally as a snowflake was

foreign to them. They reacted to it as many Christian fundamentalists responded to Darwin: no design without a Designer!

Marxist fundamentalists reacted in a similar way when, after World War I, they undertook to construct the new socialist economies of eastern Europe. It took them some thirty years to realize that markets and prices might play a constructive role in socialist economies and might even have important advantages over central planning as tools for the allocation of resources. My sometime teacher, Oscar Lange, was one of the pioneers who carried this heretical notion to Poland after the Second World War and risked his career and his life for the idea.

With the collapse of the Eastern European economies around 1990 the simple faith in central planning was replaced in some influential minds by an equally simple faith in markets. The collapse taught that modern economies cannot function well without smoothly operating markets. The poor performance of these economies since the collapse has taught that they also cannot function well without effective organizations.

If we focus on the equilibrating functions of markets and put aside the illusions of Pareto optimality, market processes commend themselves primarily because they avoid placing on a central planning mechanism a burden of calculation that such a mechanism, however well buttressed by the largest computers, could not sustain. Markets appear to conserve information and calculation by assigning decisions to actors who can make them on the basis of information that is available to them locally—that is, without knowing much about the rest of the economy apart from the prices and properties of the goods they are purchasing and the costs of the goods they are producing.

No one has characterized market mechanisms better than Friederich von Hayek who, in the decades after World War II, was their leading interpreter and defender. His defense did not rest primarily upon the supposed optimum attained by them but rather upon the limits of the inner environment—the computational limits of human beings:12

The most significant fact about this system is the economy of knowledge with which it operates, or how little the individual participants need to know in order to be able to take the right action.


The experiments on simulated markets, described earlier, confirm his view. At least under some circumstances, market traders using a very small amount of mostly local information and extremely simple (and non-optimizing) decision rules, can balance supply and demand and clear markets.

It is time now that we turn to the role of organizations in an organization—&-market economy and the reasons why all economic activities are not left to market forces. In preparation for this topic, we need to look at the phenomena of uncertainty and expectations.

Uncertainty and Expectations
Because the consequences of many actions extend well into the future, correct prediction is essential for objectively rational choice. We need to know about changes in the natural environment: the weather that will affect next year's harvest. We need to know about changes in social and political environments beyond the economic: the civil warfare of Bosnia or Sri Lanka. We need to know about the future behaviors of other economic actors—customers, competitors, suppliers—which may be influenced in turn by our own behaviors.

In simple cases uncertainty arising from exogenous events can be handled by estimating the probabilities of these events, as insurance companies do—but usually at a cost in computational complexity and information gathering. An alternative is to use feedback to correct for unexpected or incorrectly predicted events. Even if events are imperfectly anticipated and the response to them less than accurate, adaptive systems may remain stable in the face of severe jolts, their feedback controls bringing them back on course after each shock that displaces them. After we fail to predict the blizzard, snowplows still clear the streets. Although the presence of uncertainty does not make intelligent choice impossible, it places a premium on robust adaptive procedures instead of optimizing strategies that work well only when finely tuned to precisely known environments.13

Expectations. A system can generally be steered more accurately if it uses feedforward, based on prediction of the future, in combination with feedback, to correct the errors of the past. However, forming expectations to deal with uncertainty creates its own problems. Feedforward can have unfortunate destabilizing effects, for a system can overreact to its predictions and go into unstable oscillations. Feedforward in markets can become especially destabilizing when each actor tries to anticipate the actions of the others (and hence their expectations).

The standard economic example of destabilizing expectations is the speculative bubble. Bubbles that ultimately burst are observed periodically in the world’s markets (the Tulip Craze being one of many well-known historical examples). Moreover, bubbles and their bursts have now been observed in experimental markets, the overbidding occurring even though subjects know that the market must again fall to a certain level on a specified and not too distant date.

Of course not all speculation blows bubbles. Under many circumstances market speculation stabilizes the system, causing its fluctuations to become smaller, for the speculator attempts to notice when particular prices are above or below their “normal” or equilibrium levels in order to sell or buy, respectively. Such actions push the prices closer to equilibrium. Sometimes, however, a rising price creates the expectation that it will go higher, hence induces buying rather than selling. There ensues a game of economic “chicken,” all the players assuming that they can get out just before the crash occurs. There is general consensus in economics that destabilizing expectations play an important role in monetary hyperinflation and in the business cycle. There is less consensus as to whose expectations are the first movers in the chain of reactions or what to do about it.

The difficulties raised by mutual expectations appear wherever markets are not perfectly competitive. In perfect competition, each firm assumes that market prices cannot be affected by their actions: prices are as much a part of the external environment as are the laws of the physical world.

But in the world of imperfectly competitive markets, firms need not make this assumption. If, for example, there are only a few firms in an industry, each may try to outguess its competitors. If more than one plays this game, even the definition of rationality comes into question.

The Theory of Games. A century and a half ago, Augustin Cournot undertook to construct a theory of rational choice in markets involving two firms. He assumed that each firm, with limited cleverness, formed an expectation of its competitor’s reaction to its actions, but that each carried the analysis only one move deep. But what if one of the firms, or both, tries to take into account the reactions to the reactions? They may be led into an infinite regress of outguessing.

A major step toward a clearer formulation of the problem was taken a century later, in 1944, when von Neumann and Morgenstern published The Theory of Games and Economic Behavior. But far from solving the problem, the theory of games demonstrated how intractable a task it is to prescribe optimally rational action in a multiperson situation where interests are opposed.

The difficulty of defining rationality exhibits itself well in the so-called Prisoners’ Dilemma game. In the Prisoners’ Dilemma, each player has a choice between two moves, one cooperative and one aggressive. If both choose the cooperative move, both receive a moderate reward. If one chooses the cooperative move, but the other the aggressive move, the cooperator is penalized severely while the aggressor receives a larger reward. If both choose the aggressive move, both receive lesser penalties. There is no obvious rational strategy. Each player will gain from cooperation if and only if the partner does not aggress, but each will gain even more from aggression if he can count on the partner to cooperate. Treachery pays, unless it is met with treachery. The mutually beneficial strategy is unstable.

Are matters improved by playing the game repetitively? Even in this case, cleverly timed treachery pays off, inducing instability in attempts at cooperation. However, in actual experiments with the game, it turns out that cooperative behavior occurs quite frequently, and that a tit-for-tat strategy (behave cooperatively until the other player aggresses; then aggress once but return to cooperation if the other player also does) almost always yields higher rewards than other strategies. Roy Radner has shown (personal communication) that if players are striving for a satisfactory payoff rather than an optimal payoff, the cooperative solution can be stable. Bounded rationality appears to produce better outcomes than unbounded rationality in this kind of competitive situation.

The Prisoners' Dilemma game, which has obvious real-world analogies in both politics and business, is only one of an unlimited number of games that illustrates the paradoxes of rationality wherever the goals of the different actors conflict totally or partially. Classical economics avoided these paradoxes by focusing upon the two situations (monopoly and perfect competition) where mutual expectations play no role.

Market institutions are workable (but not optimal) well beyond that range of situations precisely because the limits on human abilities to compute possible scenarios of complex interaction prevent an infinite regress of mutual outguessing. Game theory's most valuable contribution has been to show that rationality is effectively undefinable when competitive actors have unlimited computational capabilities for outguessing each other, but that the problem does not arise as acutely in a world, like the real world, of bounded rationality.

Rational Expectations. A different view from the one just expressed was for a time popular in economics: that the problem of mutual outguessing should be solved by assuming that economic actors form their expectations "rationally."1 This is interpreted to mean that the actors know (and agree on) the laws that govern the economic system and that their predictions of the future are unbiased estimates of the equilibrium defined by these laws. These assumptions rule out most possibilities that speculation will be destabilizing.

Although the assumptions underlying rational expectations are empirical assumptions, almost no empirical evidence supports them, nor is it obvious in what sense they are "rational" (i.e., utility maximizing). Business firms, investors, or consumers do not possess even a fraction of the knowledge or the computational ability required for carrying out the rational expectations strategy. To do so, they would have to share a model of the economy and be able to compute its equilibrium.

Today, most rational expectationists are retreating to more realistic schemes of "adaptive expectations," in which actors gradually learn about their environments from the unfolding of events around them.18 But most approaches to adaptive expectations give up the idea of outguessing the market, and instead assume that the environment is a slowly changing "given" whose path will not be significantly affected by the decisions of any one actor.

In sum, our present understanding of the dynamics of real economic systems is grossly deficient. We are especially lacking in empirical information about how economic actors, with their bounded rationality, form expectations about the future and how they use such expectations in planning their own behavior. Economics could do worse than to return to the empirical methods proposed (and practiced) by George Katona for studying expectation formation,19 and to an important extent, the current interest in experimental economics represents such a return. In face of the current gaps in our empirical knowledge there is little empirical basis for choosing among the competing models currently proposed by economics to account for business cycles, and consequently, little rational basis for choosing among the competing policy recommendations that flow from these models.


18. T. J. Sargent, *Bounded Rationality in Macroeconomics* (Oxford: Clarendon Press, 1993). Note that Sargent even borrows the label of "bounded rationality" for his version of adaptive expectations, but, regretfully, does not borrow the empirical methods of direct observation and experimentation that would have to accompany it in order to validate the particular behavioral assumptions he makes.

Business Organizations

We turn now to the great mass of economic activity that takes place within the internal environments of organizations. The key question here, one much discussed in "the new institutional economics" (NIE), is: what determines the boundary between organizations and markets; when will one be used, and when the other, to organize economic activity?

The Organization-Market Boundary. At the outset it should be observed that the boundary is often quite movable. For example, retail sales of automobiles are usually handled by dealerships, organizations with separate ownership from the manufacturers. Many other commodities are sold directly to consumers by manufacturers, and in some industries (e.g., fast foods) there is a combination of direct outlets and franchise agencies. The franchise is an excellent example of a hybrid species, as is the sole-source vendor who supplies raw materials or parts to a manufacturer.

We take the frequent movability or indefiniteness of organizational boundaries as evidence that often there is nearly a balance between the advantages of markets and organizations. Nevertheless we recall again the vast activity that takes place inside organizations, many of them very large, as an indication that in many circumstances they offer important advantages over markets.

The NIE explanation for sometimes preferring organizations to markets is that certain kinds of market contracts incur transaction costs that can be avoided or reduced by replacing the sales contract by an employment relation. On the other hand, as all economic actors are supposed by the NIE theory to be motivated by selfish interest, organizations incur the costs of rewarding their employees for following organizational goals instead of personal interest and on supervising them to see that they do so.

This account of the relative advantages of the two institutions misses essential parts of the story, especially the opportunities for decentralization of decision making within organizations. These opportunities de-


pend, in turn, upon the strength of the loyalties of employees to their organizations, and their identification with organizational objectives that derive from loyalty and from the local informational environment in which they find themselves.

Decentralization. Organizations are not highly centralized structures in which all the important decisions are made at the center. Organizations operating in that centralized way would exceed the limits of human procedural rationality and lose many of the advantages attainable from the use of hierarchical authority. Real-world organizations behave quite differently.

As a single decision may be influenced by a large number of facts and criteria of choice, some fraction of these premises may be specified by superiors without implying complete centralization. Organizations can localize and minimize information demands just as markets do, by decentralizing decisions. Matters of fact can be determined wherever the most skill and information is located to determine them, and they can then be communicated to "collecting points" where all the facts relevant to an issue can be put together and a decision reached. We can think of a decision as produced by executing a large computer program, each subroutine having its special tasks and relying on local sources of information. No single person or group need be expert on all aspects of the decision.

Thus business organizations, like markets, are vast distributed computers whose decision processes are substantially decentralized. The top level of a large corporation, which is typically subdivided into specialized product groups, will perform only a few functions, most often: (1) the "investment banking" function of allocating funds for capital projects, (2) selection of top executive personnel, and (3) long-range planning for capital funds and for possible new activities outside the scope of existing divisions.

Markets and organizations, however decentralized, are not fully equivalent in their effects. None of the theorems of optimality in resource

allocation that are provable for ideal competitive markets can be proved for hierarchies, but this does not mean that real organizations operate inefficiently as compared to real markets.

Externalities. Economists sometimes state the case for organizations as opposed to markets in terms of externalities. Externalities arise because the price mechanism works as advertised only when all of the inputs and outputs of an activity are subject to market pricing. A traditional example of an externality is a factory that is allowed to spew smoke from its stacks without compensating the surrounding homeowners. In these circumstances the price mechanism will not secure a socially desirable level of manufacturing activity; the product, priced below its social cost, will be overused.

The economist's preferred remedy for externalities is to bring the undesired consequences within the calculus of the price system: tax the emission of smoke, for example. This raises the question of how the tax is to be set. Although the techniques of cost-benefit analysis can provide answers, they are administrative answers and not answers given by an automatic market mechanism.

Similar questions of externalities among corporate divisional operations make large corporations less than fully willing to allow transactions among their component divisions and departments to be governed wholly by internal markets. In the absence of perfect competition, internal market prices are administered or negotiated prices, not competitive prices.

Uncertainty. Uncertainty often persuades social systems to use hierarchy rather than markets in making decisions. It is not reasonable to allow the production department and the marketing department in the widget company to make independent estimates of next year's demand for widgets if the production department is to make the widgets that the marketing department is to sell. In matters like this, and also in matters of product design, it is more preferable that all the relevant departments operate on the same body of assumptions even if (or perhaps "especially if") the uncertainties might justify quite a range of different assumptions. In facing uncertainty, standardization and coordination, achieved through agreed-upon assumptions and specifications, may be more effective than prediction.

Uncertainty calls for flexibility, but markets do not always provide the greatest flexibility in the face of uncertainty. All depends on the sources of the uncertainty. If what is uncertain is a multitude of facts about individual and separate markets, then decentralized pricing will appear attractive; if the uncertainty encompasses major events that will affect many parts of the organization in the same direction, then it may be advantageous to centralize the making of assumptions about the future and to require the decentralized units to use these assumptions in their decisions.

Uncertainty is especially troublesome when it involves expectations by one unit about what other units in the same organization will do. Left to the market, this kind of uncertainty leads directly to the dilemmas of rationality that we described earlier in terms of game theory and rational expectations. Absorption of the uncertainty by the organization through managerial coordination may be the most effective course. We see in uncertainty a frequent source of advantage of organizations over markets as decision-making mechanisms.

In a world of bounded rationality there are several ways to amplify the computing capabilities of individual human beings and enhance the possibilities of their collective survival and prosperity. With the combined use of markets and administrative hierarchies, the human species has enormously increased its capabilities for specialization and division of work. It would be too much to attribute the vast growth and spread of human populations to such mechanisms alone—modern medicine and modern technology have had something to do with it too—but the (perhaps temporary) dominance of our species over the globe today is witness to the augmentation of human reason—applied to local, not global, concerns—that has been made possible by these social artifacts.

Organizational Loyalties and Identifications

Brief mention was made earlier of a crucial reason why so much human activity takes place within organizations: people acquire loyalty, and often a large amount of loyalty, to the groups, including organizations, to which they belong.

Consequences of Identification. Organizational loyalty is perhaps better labeled identification, for it is both motivational and cognitive. The motivational component is an attachment to group goals and a willingness to
work for them even at some sacrifice of personal goals. (In effect, the group goals become personal goals.) The ethic conflict we observe in many parts of the world provides vivid evidence of this attachment to group goals and the differential treatment it generates between "we" and "they."

Identification with an organization also has a cognitive component, for members are surrounded by information, conceptions and frames of reference quite different from those of people outside the organization or in a different organization. As creatures of bounded rationality, incapable of dealing with the world in all of its complexity, we form a simplified picture of the world, viewing it from our particular organizational vantage point and our organization's interests and goals.

This frame of reference and information provided by an organization influence strongly the processing and outcomes of decisions. The frame of reference varies, too, from one organization unit to another, and from one level to another, so that each employee may identify at one time with his department, at another with his section, at another with the whole company.

Affected by their organizational identifications, members frequently pursue organizational goals at the expense of their own interests—that is to say, behave in a way that is altruistic from a personal standpoint. No organization could survive that elicited only behavior for which employees felt selfishly rewarded and that supervisors could enforce. The added effort that is elicited by identification is a major and essential source of organizational effectiveness and is a principal reason for carrying out economic activities in organizations rather than markets.

Evolutionary Basis for Identification. It may be objected that human beings are basically selfish and do not behave in this altruistic fashion. In fact, neo-Darwinian evolutionary theory has generally claimed that altruism, except to close relatives, is inconsistent with the basic postulate that organisms evolve to increase their fitness. However, I should like to show that this widely repeated claim is mistaken.


Because of their bounded rationality, and because they can therefore greatly enhance their limited knowledge and skill by accepting information and advice from the social groups to which they belong, individuals who are docile—who tend to accept such information and advice—have a great advantage in fitness over those who are not docile—who reject social influence. Docile people do not have to learn about hot stoves by touching them.

Most social influence does enhance the fitness of the recipient. It provides information and advice about the world that is generally valid—or at least much more informative and valid than the information the recipient could generate independently. But docility can be "taxed" by influencing people also to take certain actions that are not personally beneficial but are beneficial to the group. As long as the "taxation" is not so heavy as to cancel the advantages of docility, the altruistic individual will be fitter than the non-docile individual. By this means, the fitness of the organization will be enhanced by the docility, hence altruism, of its members. Although, docility is generally rewarding to the individual, some fraction of the behavior it induces is altruistic in this sense, and this altruism is an important factor in the efficacy of organizations.

We can summarize our account of the respective roles of markets and organizations in a modern society as follows: (1) organizations find their niches wherever constellations of interdependent activities are best carried out in coordinated fashion in order to remove the need for individuals' outguessing each other; (2) the human motivation that makes organizations viable and alleviates the public goods problems that arise when individual efforts cannot be tied closely to individual rewards is provided by organizational loyalty and identification; (3) in both organizations and markets, the bounds on human rationality are addressed by arranging decisions so that the steps in decision making can depend largely on information that is locally available to individuals.

The Evolutionary Model

Evolutionary processes are significant not only for explaining organizational loyalty, but also for describing and explaining the historical development of economic institutions, including business firms. The simplest
scheme of evolution depends on two processes: a generator and a test. The generator produces variety, new forms that have not existed previously, whereas the test culls out the generated forms so that only those that are well fitted to the environment will survive. In modern biological Darwinism, genetic mutation and crossover of chromosomes are the principal generators, and natural selection is the test.

The Alternative Theory of Economic Man
No one supposes that a modern organization-market economy is the product of deliberate design. Surely it evolved from earlier subsistence economies, shaped by myriad decisions made by hosts of actors over thousands of years. By contrast, most accounts of business firms assume that actors deliberately select actions appropriate to their goals within the context of the given economic environment. Adaptation, in the latter accounts, stems from selection by rational actors, not by natural selection of those actors whose behavior happens to be adaptive. An evolutionary theory of the firm might argue that it does not matter whether people maximize or satisfice, for in a world of competitive markets only those who make decisions as if they were maximizing will survive.23 Does this evolutionary argument in fact imply optimization?

Our discussion will have implications for biology as well as economics, for evolutionary biology uses the language of optimality quite freely and in recent years has even borrowed linear programming and other OR techniques to predict the outcomes of natural selection in biological systems. This is legitimate only if optimization would lead reliably to the same equilibria as would natural selection.

Local and Global Maxima
For the question before us, the difference between local and global maxima is crucial. In the landscape of California every tiny hill is a local max-


imum of altitude, but only Mt. Whitney is a global maximum. For many purposes it makes a difference whether one finds oneself standing on Nob Hill or Mt. Whitney. Finding a local maximum is usually easy: walk uphill until there is no place to walk. Finding the global maximum, on the other hand, is usually exceedingly complex unless the terrain has very special properties (no local maxima). The world of economic affairs is replete with local maxima. It is quite easy to devise systems in which each subsystem is optimally adapted to the other subsystems around it, but in which the equilibrium is only local, and quite inferior to distant equilibria that cannot be reached by the up-hill climb of evolution.

The Myopia of Evolution
Darwinian evolution is completely myopic. At each incremental step the evolving organism becomes fitter relative to its current environment, but there is no reason for the progress to lead to a global maximum of fitness of the individuals, separately or severally. If we are considering this kind of system, whose environment has a multitude of local maxima, we cannot understand the system unless we know something of the method and history of its evolution. Nor is there any reasonable sense in which such a system can be regarded as "fittest."

This is not just an in-principle objection to confounding hill climbing with optimization. In a myopic hill-climbing system, it may be difficult or impossible to move from a local maximum to another that is in view across a deep valley: The movement from the English system of measures to the metric system is a case in point. A society starting from scratch, and familiar with both systems, would surely prefer the metric to the English system. But if future benefits are discounted at some rate of interest, it might never be economical to switch from the one system, once adopted, to the other.

Hence, from the fact that an economic system is evolving, one cannot conclude that it has reached or is likely to reach a position that bears any resemblance to the equilibria found in the theory of perfect competition. Each species in the ecosystem is adapting to an environment of other species evolving simultaneously with it. The evolution and future of such systems can only be understood from a knowledge of their histories.
The Mechanisms of Economic Evolution

If the adaptation of both the business firm and biological species to their respective environments are instances of heuristic search, hence of local optimization or satisficing, we still have to account for the mechanisms that bring the adaptation about. In biology the mechanism is located in the genes and their success in reproducing themselves. What is the gene's counterpart in the business firm?

Nelson and Winter suggest that business firms accomplish most of their work through standard operating procedures—algorithms for making daily decisions that become routinized and are handed down from one generation of executives and employees to the next. Evolution derives from all the processes that produce innovation and change in these algorithms. The fitness test is the profitability and growth rate of the firm. Profitable firms grow by the reinvestment of their profits and their attractiveness for new investment.

Nelson and Winter observe that in economic evolution, in contrast to biological evolution, successful algorithms may be borrowed by one firm from another. Thus the hypothesized system is Lamarckian, because any new idea can be incorporated in operating procedures as soon as its success is observed, and hence successful mutations can be transferred between firms. Transfer is of course not costless, but involves learning costs for the adopting firm. It may also be impeded by patent protection and commercial secrecy. Nevertheless, processes of the kinds just described play a large role in the gradual evolution of an economic system composed of business firms.

From these considerations, one sees that the evolution of firms and of economies does not lead to any easily predictable equilibrium, much less an optimum, but it is a complex process, probably continuing indefinitely, that is probably best understood through an examination of its history. As in any dynamic system that has propensities for following diverging paths from almost identical starting points, equilibrium theories of an economy can tell us little about either its present state or its future.


Human Society

Economics has been unfairly labeled the "gloomy" science, for in its Ricardoian form, incorporating Malthusian views of the pressure of population on resources, it did not hold out much hope for human progress. The label is unfair, because economics in fact draws a romantic, almost heroic, picture of the human mind. Classical economics depicts humankind, individually and collectively, as solving immensely complex problems of optimizing the allocation of resources. The artfulness of the economic actors enables them to make the very best adaptations in their environments to their wants and needs. In this chapter, while keeping the adaptive capabilities of mind in the center of things, I have tried to suggest a more complex state of affairs. A veridical picture of economic actors and institutions must incorporate the information processing limits set by their inner environments. The picture must also accommodate both the conscious rationality of decision makers and the unplanned but adaptive evolutionary processes that have molded economic institutions.

Operations research and artificial intelligence have enhanced the procedural rationality of economic actors, helping them to make better decisions. On a larger scale, markets and organizations are social schemes that facilitate coordinated behavior, at the same time conserving the critical scarce resource of human ability to handle complexity and great masses of information. In this chapter I have not tried to evaluate these forms of individual and social organization, but simply to describe them as commonly used solutions to the central human problem of accommodating to our bounded rationality.

The analysis shows that a deeper understanding of the tools of procedural rationality requires a closer examination of how the human mind works, of the limits on human rationality. The next two chapters will describe what has been learned in the past half century about human information processing. Chapter 3 will focus on problem solving processes and general cognitive architecture, chapter 4 on memory and learning processes.