Bounded Rationality in Industrial Organization[1]

Glenn Ellison
MIT and NBER

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Abstract

This paper discusses the use of bounded rationality in industrial organization. There is a long tradition of such work: literatures from various decades have discussed irrationalities by firms and consumers. Three main approaches are found in the recent literature: rule-of-thumb papers specify simple rules for behavior; explicit bounds papers consider agents who maximize payoffs net of cognitive costs; the psychology and economics approach typically cites experimental evidence to motivate utility-like framworks. Common to each recent literature is a focus on consumer irrationalities that firms might exploit. I discuss several new topics that have been opened up by the consideration of bounded rationality and new perspectives that have been provided on traditional topics.

1 Introduction

In the last few years there has been a surge of interest in bounded rationality in industrial organization. The field has attracted the attention of a remarkable collection of top young researchers from industrial organization and behavioral economics. Much of the recent interest has been spurred by developments in psychology and economics, but there is also a longstanding tradition of such work in industrial organization. Although the field is not yet as coherent and advanced as most fields surveyed at an Econometric Society World Congress, the fact that diverse strands of research and diverse researchers are coming together seemed to me to make it a topic for which a discussion could be useful.

The terms "boundedly rational" and "behavioral" have been used by different groups of economists over the years to describe different styles of work. The "bounded rationality" in my title is interpreted broadly, and includes work from three different traditions. One tradition I call the rule-of-thumb approach. These papers typically assume directly that consumers or firms behave in some simple way, rather than deriving behavior as the solution to a maximization problem. A second tradition is what I call the "explicit bounded rationality" approach. In this literature, cognition is costly, and agents adopt second-best behaviors taking these costs into account. The third tradition examines what happens in industrial organization settings when consumers are subject to behavioral biases identified in the psychology and economics literature.

The primary motivation for boundedly rational analysis is common across three traditions: in many situations the "rational" model does not seem plausible or has a hard time incorporating factors that seem important. There are also other motivations. One is that after twenty years of dominance of the game-theoretic paradigm, boundedly rationality explanations have been much less worked over. Another is that boundedly rational models are sometimes more tractable than rational models and make it feasible to enrich one's analysis in other dimensions.

Although rational game-theoretic approach has dominated IO for the past twenty five years, the idea of using bounded rationality is far from new. This World Congress coincides with the 50th anniversary of Simon's (1955) call to replace the rational economic man with a boundedly rational counterpart. Next year is the 50th anniversary of Strotz's (1956) seminal work on time inconsistency. The rule-of-thumb approach is even older. The application of these ideas to industrial organization has waxed and waned, but by now it amounts to a substantial literature.

I begin this essay with a discussion of several old literatures. I do this both because I think it is useful to recount what happened before 1990, and because it provides an opportunity to explain what the different boundedly rational approaches are, what are their strengths and weaknesses, and where they have been most successful. I think all three methodologies are useful and that anyone interested in boundedly rational industrial organization should be fluent with each of them.

I then turn to the more recent literature on boundedly rational IO. Here, I see the literature as having divided into two main branches. The first is growing out of the industrial organization literature. Papers in this branch typically begin with one of two observations: the IO literature on some topic is unsatisfying because aspects of the existing rational models aren't compelling; or the IO literature has had little to say about some topic (perhaps because rational modeling would have been awkward). They then propose models with some boundedly rational elements and discuss how they add to the literature on the topic. The second branch is growing out of the psychology and economics literature. Papers in this branch typically start by noting that the psychology and economics literature has shown that consumers depart from rationality in some particular way. They then explore how a monopolist would exploit such a bias, what the effects would be under competition, etc. I provide overviews of each of these literatures and discuss some general themes.

Readers of this survey will note that the literatures I discuss remain sparse. Most topics in IO have little or no boundedly rational work on them. Most behavioral biases have received little or no consideration in IO, and even when they have been discussed it is only the most basic IO questions that have been asked. This makes it an exciting time to work in the field.

2 Early History

It is impossible to identify the beginnings of bounded rationality in industrial organization. Throughout the period when the neoclassical profit-maximizing model was being developed there were spirited debates between proponents and opponents of "marginal revenue = marginal cost" as a foundation for firm behavior. Hall and Hitch (1939), for example, take direct aim at economists who "assume the general relevance of the simple analysis in terms of marginal cost and marginal revenue" and "that production is carried out to the point where this elasticity is equal to the ratio $\frac{P}{P-MC}$." They report that interviews of 38 business executives

> ... casts doubt on the general analysis of price and output policy in terms of marginal cost and marginal revenue ... they are thinking in altogether different terms; that in pricing they try to apply a rule of thumb we call 'full cost'."

Hall and Hitch were mostly concerned with debating the modeling of firm behavior, but other papers from the 1920's, 1930's, and 1940's were more directly focused on industrial organization implications. Rothschild (1947) is a delightful example that in many ways is quite like modern behavioral IO papers. It assumes that a firm's "desire for secure profits" is a second objective as important as the desire for maximum profits and discusses various implications in oligopoly settings. For example, it argues that this can lead to price rigidity, to varying contractual terms-of-trade, to price wars, to political actions, etc. He sees the firms in his paper as practicing full cost pricing beause they are rational with a different objective function rather than irrational, but would rather throw out rationality than full-cost pricing if his rationalization proves incorrect: "if business behaviour were really irrational, this would not serve as an excuse for the neglect of such behavior. Irrationality would then have to become one of the premises of oligopolistic price theory." Analytically, of course, the paper is quite different from modern work. The conclusions are drawn from very loose verbal arguments. Rothschild is, however, prescient in recognizing this limitation. He explains that "A completely novel and highly ingenious general theoretical apparatus for such a solution of the oligopoly problem has recently been created by

John von Neumann and Oskar Morganstern ... Unfortunately, at the time of writing this article I had no opportunity of obtaining a copy of this important book."

One tends to think that there was a long era of neoclassical dominance betweeen the death of this old literature and the birth of interest in post-rationality bounded rationality. In this light, I find it noteworthy that less than a decade separates the publication of Rothschild's paper and the publication of Simon's (1955) "A Behavioral Model of Rational Choice." Simon is clearly writing for an audience steeped in rationality and sells his bounded rationality as an enhancement of the prevailing paradigm:

> the task is to replace the global rationality of economic man with a kind of rational behavior that is compatible with the access to information and the computational capacities that are actually possessed by organisms.

Simon discusses the various challenges involved in optimization. His critiques and visions for a new framework are compelling. The progress he makes toward this goal is less satisfying. He mostly ends up emphasizing a "satisficing" model in which agents search for actions until they find one that achieves a payoff that provides them with at least some aspiration level.

Cyert and March (1956) is an early application to industrial organization. In the modern style, they start by citing interesting papers from the psychology literature to justify their assumptions about deviations from profit-maximization.[1] Among the implications of satisficing they discuss are that firms are most likely to expand sales when profits are low and costs high, and that dominant firms may tend to lose market share over time. The analytic methodology, of course, is still far from modern: other than one set of diagrams using Stigler's dominant firm model, the analysis is completely informal. They do present empirical data related to their hypotheses.

One aspect of this literature that is striking in contrast to the current literature is that the focus is almost exclusively on firms' deviations from profit-maximization rather than on consumer irrationality. Indeed, consumers are rarely mentioned. Their presence is, of

[1]For example, the notion that people satisfice is supported by the experiments showing that subject who are asked to throw darts as close to the center of a target as possible are more accurate when the target is smaller.

course, implicit in the assumption that the firm is facing a specified demand curve. Perhaps this is why consumer irrationality was not discussed. Whether the demand curve reflects the aggregation of utility-maximizing decisions or some other consumer behavior would not really affect the analysis.

3 Bounded Rationality at the Time of the Game-Theoretic Revolution

The late 1970's and early 1980's is usually thought of as the beginning of the game-theoretic revolution in Industrial Organization. It was also a time when several distinct "boundedly rational" or "behavioral" approaches were being developed.

3.1 The rule-of-thumb approach

Consider the simple problem a consumer faces on every trip to the supermarket: should he buy any of the dozens of relatively new products he has never tried or should he continue to buy what he habitually buys. To make a rational decision the consumer must start with a prior over the quality of the unknown goods, he must also have a prior over how quality covaries with cost and think through what this implies about the signals inherent in the price of the good and the amount of shelf space the store has devoted to the product. Whether by observing other shoppers or talking to friends, the consumer will also learn something about the popularity of the product. Correctly accounting for this signal requires a correct prior over the set of possible social processes by which popularity has been achieved. How long has the product been on the shelf before I noticed it? Are the previous consumers people who have used the good before or people trying it for the first time? How many previous customers did they talk to before trying it? What did they know about where those customers got their information and how they used it? Recent models by Banerjee (1992), Bikhchandani, Hirshleifer and Welch (1992), Banerjee and Fudenberg (2004), and Bose, Orosel, Ottaviani, and Vesterlund (2006) provide remarkable analyses showing that the rational approach can be made tractable in some such situations.

Despite my admiration for these papers, when I think about consumers' making such decisions dozens of times in the course of an hour-long shopping trip I have the same reaction that Smallwood and Conlisk (1979) had when contemplating this problem twenty-five years ago:

> ... a would-be optimizing consumer who took account of market popularities would be involved in a massive game theory problem with all other consumers. Is it really plausible that he could solve the game?

The approach of the rule-of-thumb literature is to simply posit rules of thumb that consumers are assumed to follow. One can think of this as similar to the game-theoretic approach, but skipping the part of the argument in which one posits utility functions and derives the behaviors as optimizing choices. Proponents of the rule-of-thumb approach see it as having two advantages. First, in some models it seems implausible that consumers would do the "rational" calculations. A desiderata for choosing a rule-of-thumb is that the explicitly assumed consumer behavior should be more believable than the behavior implicitly assumed in the obvious rational alternatives. Second, rule-of-thumb papers tend to provide more analysis of robustness. One reason is inherent: the analysis of rule-of-thumb models is simpler, making it possible to analyze more variants in the same amount of time. Another is probably sociological: rule-of-thumb authors recognize that they will be subject to more scrutiny than their "rational" peers and must head off critiques about the conclusions being nonrobust to changes in the ad hoc assumptions.

Smallwood and Conlisk's (1979) model of the effect of product quality on market share remains a beautiful example of the rule-of-thumb approach. Consider a market in which consumers choose between K brands at $t = 0, 1, 2, \ldots$. Suppose that a consumer of product i in period t experiences a "breakdown" with probability b_i. This could be a literal breakdown of a durable good or just a disappointing experience with an ordinary consumable.

In this environment, Smallwood and Conlisk examine what happens when consumers follow particular rules of thumb. Specifically, they assume each consumer continues to use the same product until he experiences a breakdown. When a breakdown occurs he considers switching and ends up choosing product i with probability proportional to $m_i(t)^\sigma$, where $m_i(t)$ is the market share of product i. By varying the parameter σ the assumption can encompass a range of behaviors. For example, $\sigma = 0$ is purely random choice, and $\sigma = 1$ models consumers who ask one randomly selected friend which brand they used and purchase that product.

The first theorems in the paper explore the connection between behavior at the consumer level and the efficiency of product adoption. For example, they show that when $\sigma < 1$, higher quality products eventually become more popular regardless of the initial conditions, but all products have positive market shares in the long run. When $\sigma > 1$ this is not true and an inferior product can come to dominate the market if its initial market share is sufficiently high. A particularly interesting feature of the model is that when $\sigma = 1$ the highest quality product (or products) always dominates in the long run. In this sense, we see that limited rationality at the individual level – recall that $\sigma = 1$ means copying the decision made by one randomly chosen user without using any information about their satisfaction – can make product adoption socially optimal in the long run. When this happens, it makes the rule-of-thumb assumption all the more palatable: there is no strong incentive to deviate to some more complex behavior.

The Smallwood-Conlisk paper has other features that presage future developments in boundedly rational IO. Stylistically, it includes a quick reference to some work by Tversky to motivate the assumption of bounded rationality. More substantively, the second half of the paper pairs irrational consumers with strategic firms to endogenize the product qualities:

> Firms, unlike consumers, will be assumed to solve optimization problems in choosing their $b_i(t)$. A rationale is that firms are better able to compute optima and are penalized more if they do not (through the force of competition.)

In the recent psychology and economics-motivated literature the rational firm-irrational consumer assumption has become the norm, and the question of what firms do to exploit irrationality is often the primary focus.

When the game-theoretic revolution swept through industrial organization, much of rule-of-thumb literature could not withstand the onslaught. For example, Schmalensee (1978) used a rule-of-thumb approach to analyze a model in which higher quality products were more costly to produce and firms chose advertising levels. He argues for the rule-of-thumb approach over the rational approach on the grounds that "it seems implausible to assume that households actually compute optimal solutions to a large number of difficult game-theoretic and information-theoretic problems." Part of his argument for this contention is that "buyers' optimal use of the signals transmitted by firms's choices of advertising levels would depend on the strategies being employed by all sellers." Within just a few years, the mechanics of solving such signalling problems had become so routine that I am sure few economists presented with this latter quote would have guessed that it was meant as a critique of signalling theory rather than as an exposition of how to solve signalling problems.

3.2 Explicit bounded rationality

Although Simon's initial motivation of bounded rationality leaned very heavily on limited human capacity for computation, the theory mostly developed along lines that had little to do with this. Agents were assumed to satisfice rather than to maximize, but there was little attempt to formalize why this might be easier than maximizing or to provide criterion on which to assess the feasibility of other behaviors.

One place in which computational limitations were made explicit was in team theory.[2] In the canonical model of this literature, a firm is modeled as a group of agents sharing a common objective. The firm needs to choose a vector-valued action. Which action is optimal depends on an unknown state of nature. Each employee has some information. The problem of choosing an optimal action is complicated by the presence of two additional costs: each agent may incur a cost of gathering information; and there may be costs of communicating information across agents. Given these information costs, it will generally not be optimal to gather all the available information, nor to convey what has been gathered to a single decision maker. Instead, the firm may want to decentralize decision-making and have agents or groups of agents choose components of the vector-valued action independently.

Making decisions according to the optimal decentralized procedure is, of course, the

[2] See Marschak and Radner (1972).

fully rational thing to do in this model if one takes all costs into account. It can thus be seen as providing a rational analysis of why firms are organized as they are. Team theory models can also, however, be seen as tool for looking at a range of industrial organization problems. The idea is that team theory provides information-cost-based microfoundations that can guide our choice of rules of thumb. The traditional analysis of monopoly and oligopoly problems ignores information costs. Hence, what we call "rational" models are really rule-of-thumb models that assume firms use a particular rule of thumb: behave as if information costs were not present. If team theory gives us some general insights into how information costs affect firm behavior, then analyzing IO problems by using rules-of-thumb suggested by team theory should be superior to the "rational" approach as it is conventionally applied.

Radner's (1975) model of cost-reduction by satisficing managers connects with both the explicit bounds and the rule-of-thumb literatures. He examines the problem of a firm that has only limited managerial attention to devote to minimizing its costs. Analytically, Radner takes a rule-of-thumb approach. He defines procedures for the manager to follow and examines the consequences.

3.3 Empiricism as "behavioral economics"

The 1970s also featured a third "behavioral" approach to industrial organization that would not normally be thought of as behavioral today. Joskow's (1973) "Pricing Decisions of Regulated Firms: A Behavioral Approach," is a good example. What Joskow does in this paper is simply to estimate a probit model. The dependent variable is an indicator for whether a utility applied to the New York Public Service Commission for an increase in its electric rate. He assumes that they apply for a rate hike if and only if $X_i\beta + \epsilon_i > 0$ and estimates the parameter β. The right-hand side variables X_i include things like the firm's earnings growth.

Economists today will wonder why this would have been called "behavioral." Today, the probit model would be thought of simply as a method for estimating the firm's profit function. If the firm is rational and profits are of the form $\pi_i = X_i\beta + \epsilon_i$, with ϵ_i a normally distributed component of profits that is unobserved by the econometrician, then the probit model provides a consistent estimate of β. Suppose, however, that profits are not actually linear. In the rational paradigm one assumes that firms fully understand the nonlinearities, but in many cases it would be equally plausible to assume that firms are unaware of the nonlinearities and follow an irrational rule-of-thumb of applying for a rate hike whenever $X_i\beta + \epsilon_i > 0$. In this case, the probit regression no longer estimates of profits, but it remains a consistent estimator of behavior. Whether the behavior we estimate is profit-maximizing or derived from a rule-of-thumb is irrelevant in many applications.[3]

It is because empirical work often involves directly estimating behavior (rather than utility or profit) that one can think of empirical economics as a behavioral approach. The empirical literature then becomes a place where "boundedly rational" industrial organization has quietly carried on for decades. Consider, for example, my empirical work with Judy Chevalier (1997) on risk-taking by mutual funds. We start by estimating the relationship between a mutual fund's performance in year t and how much new business it attracts in year $t + 1$. The main focus, is then on how fund companies distort their investment decisions in order to attract new business. It may be possible to provide a plausible rational explanation for the precise form of the relationship between investment returns and the inflow of new business, although my prior would be that it is not.[4] For the main question of interest, however, why consumers choose between mutual funds as they do simply doesn't matter. The initial estimates of consumer behavior tell us everything about consumers that we need to know to think about the firm's optimization problem.

A similar argument could in fact be made for much of empirical industrial organization. Consider, for example, a classic "rational" paper, Porter's (1983) study of price wars in a railroad cartel. Porter estimates a structural econometric model in which demand is assumed to be of the form $\log(Q_t) = \alpha_0 - \alpha_1 \log(P_t) + \alpha_2 Lakes_t + u_t$ and firms' supply decisions are of the form predicted by the Green-Porter model of collusion with imperfect monitoring. Again, to answer his main questions about what the firms are doing, it does not matter whether the demand curve comes from a population of consumers who are

[3]One notable exception is papers doing welfare analyses.

[4]See Lynch and Musto (2003) and Berk and Green (2004) for more on this.

optimizing some utility function or a population of boundedly rational consumers. By focusing on consumer behavior as an empirically estimable object, the approach is robust.

Discussing the whole field of empirical industrial organization is obviously far beyond what is possible in this format. For the remainder of this paper, I will treat work that is behavioral in the sense that Joskow's paper was behavioral as outside the scope of my talk.

3.4 Psychology and economics

Psychology and economics was also developing rapidly in the late 1970's and early 1980's. Kahneman and Tversky had published their work on prospect theory in *Econometrica* in 1979 and many new areas were opening up. Developments in psychology and economics have had a huge impact on the new boundedly rational IO. Many other surveys of psychology and economics are available (including two in this volume), so I won't survey developments in psychology and economics that are not focused on industrial organization.

4 Developments in the theory of bounded rationality

In the 1980's the game theoretic revolution in industrial organization seems to have been all-consuming. One can find slight departures form rationality in quite a few papers, but most seem to be unintentional or intentional shortcuts.

In the field of economic theory the situation was somewhat different. The 1982 volume of *Econometrica* is a remarkable illustration of the progress in game theory in the early 1980's: Rubinstein's bargaining paper, Kreps and Wilson's sequential equilibrium paper, Milgrom and Weber's auction paper, and Crawford and Sobel's cheap talk paper are just some of the well-known papers in that volume. By the time Tirole's *The Theory of Industrial Organization* appeared in 1988, however, theorists were already looking beyond the rational agent-equilibrium paradigm. In this section I will discuss a couple of the late 1980's developments in theory that have been important in the growth of boundedly rational industrial organization.

4.1 Learning

Fudenberg-Kreps' (1988) draft monograph "A Theory of Learning, Experimentation, and Equilibrium in Games," promoted a rule-of-thumb approach to the question of whether we should expect players to play the equilibrium of a game. Again, a two-fold argument can be made for this approach. First, a fully rational approach to the problem of how players learn to play the equilibrium of a game is unappealing — it essentially replaces the assumption that agents play the equilibrium of some simple game with the assumption that they don't know enough to do this but somehow know enough to play the equilibrium of some horribly complicated game in which agents with different information are all simultaneously learning from one another. Second, a boundedly rational approach can provide an enlightening discussion of which rules would and wouldn't lead to equilibrium play. One way to do this is to examine a variety of behavioral assumptions. Fudenberg and Kreps advocated another: they ask the reverse-engineering question of what assumptions about behavior are needed to get to particular conclusions about the outcome of the learning process.

By the early 1990's boundedly rational learning models were clearly the hot topic in game theory. Most of this literature was directed at game theorists, but several of the classic papers included little industrial-organization stories. For example, Kandori, Mailath, and Rob (1993) motivated their model using the example of a group of students buying computers in a world with network externalities.

The nicest example I know of a paper addressing a real industrial organization problem by such methods is Möbius's (2001) examination of the rise and fall of competition in local telephone service in the U.S. in the early 20th century. The basic facts about telephone competition are striking. AT&T was a monopolist in the U.S. telephone market until key patents expired in 1893/4. Eight years later, three thousand firms had built separate networks not connected to AT&T's and taken approximately half of the rapidly growing market. The entrants continued to do well for another decade or so as the market quadrupled in size. But a period of consolidation followed, and by the mid 1920's competition had essentially ended.

Möbius provides an explanation for this pattern using a rule-of-thumb learning model.

In his model, consumers and businesses are connected by social networks. The network consists of many "islands," each containing a several consumers and one business. Everyone interacts disproportionately with others in their island, but consumers also benefit from interactions with businesses on other islands. The behavior rules that describe how consumers and businesses decide between competing noninterconnected telephone networks are similar to those in Kandori, Mailath, and Rob (1993), Young (1993), and Ellison (1993). In each period most consumers take others' actions as given and choose myopically between having no phone or buying service from firm A or firm B to maximize their current period utility. Firms' decision rules are similar, but firms may also want to get two telephones so as to be accessible to consumers on both networks. A small fraction of consumers are assumed to adopt randomly in each period. Essentially, what Möbius has done with these few assumptions is to describe a Markov process governing telephone adoption. What remains is just to analyze the behavior of the process. Using both analytic results and simulations he shows how the model can account for the growth and decline of independents. Roughly speaking, what happens in the early period is that each network grows by adding new subscribers within the islands in which they are dominant. Later, the "duplication" effect becomes important. Businesses in islands dominated by the minority telephone network start to get a second phone to communicate with consumers from other islands. Once this happens, the minority network has only a weak hold on the islands it dominates and can easily lose a whole island in a chain reaction if a few friends randomly decide to switch to the majority system. He presents empirical evidence consistent with this mechanism.

Thinking about the methodology, what makes the boundedly rational approach so useful here is more related to the second advantage mentioned above. The relative tractability of making direct assumptions about behavior allows Möbius to enrich his model in a way (incorporating the social network) that that would have made it too complex to analyze had he insisted on assuming consumer rationality.

4.2 Computational complexity

Explicit concern for computational complexity entered game theory at about the same time. Rubinstein (1986) and Abreu and Rubinstein (1988) discussed complexity in the context of repeated games. In particular, they discussed the concept of strategies' being implementable by finite automata and used the number of states of an automaton as a measure of its complexity. Standard repeated game equilibria can be implemented by automata, but they note that a conundrum appears if one thinks of agents as trying both to maximize the payoffs they receive in the repeated game and to minimize costs inherent in constructing a more complex automata: agents will be tempted to leave off any states that are not reached on the equilibrium path and this may render the kinds of off-path threats necessary to support cooperation infeasible.

Fershtman and Kalai (1993) examine some IO questions using a similar complexity notion. They consider a multimarket monopoly and single- and multimarket duopoly competition. Implicit in the complexity notion is a diseconomy of multimarket operation. If there are two possible states of demand in each market, then there are 2^n possible states for the n market combination, and a fully optimizing monopolist would therefore need a plan with 2^n contingencies. They note that monopolists may want to avoid entering some markets to reduce complexity and discuss the complexity of dynamic collusion.

The models of Rubinstein (1993) and Piccione and Rubinstein (2003) discussed below develop alternate approaches to complexity. Rubinstein (1998) provides a nice survey of old and new work in this vein.

5 The New Behavioral IO: Bounded Rationality as Part of the IO Toolbox

In the 1980's it seems to have been extremely important that IO theory papers be fully rational. Today, being less that fully rational is much more acceptable. Indeed, I'd guess that at the top general interest journals an IO paper now has a better chance of being accepted if it sells itself as being "behavioral" or "boundedly rational."[5] A bias in either direction is unfortunate, but the opening of journals to boundedly rational papers is a very good thing: the legitimization of boundedly rational modeling provides an opportunity to explore new explanations for old phenomena and opens up whole new topics.

In this section and the one that follows I'll discuss recent work in boundedly rational industrial organization. The division into two sections reflects a divide I perceive in the literature in the way in which authors approach their topics. The papers I discuss in this section are topic-focused. Many grow out of existing rational IO literatures and look to bounded rationality as a complementary way to think about some phenomenon. Others discuss topics that had received little attention. In most cases, the papers have an easy time making the case that less than fully rational behavior seems implausible and that bounded rationality can provide additional insights.

I organize my discussion in this section by the IO topic being addressed.

5.1 Technology adoption

At least since Griliches's (1957) work on hybrid corn and Mansfield's (1968) work on industrial technologies there has been a recognition in industrial organization that the slow pace of technology adoption may have significant welfare consequences. Sociologists often explain slow s-shaped adoption patterns as resulting from heterogeneity in individuals attitudes toward new technologies. Rational explanations based on long machine lifetimes are also plausible for many industrial technologies. It is also clear, however, that information is important – it is not easy to know what technogies really are cost-effective – and this is an area where rationality is easy to critique. It is awkward to assume that consumers have correct priors over the set of new products that might be invented and even more awkward

[5] One anecdote to this effect is that the *Journal of Political Economy* (which I've always thought of as the ultimate proponent of rational explanations) recently explained that it was rejecting a paper not because of anything the referees said but because the editor's "gut feeling is that most of the time, forgetfulness, confusion, or other types of bounded rationality play a much more crucial role." I would hypothesize that the fact that IO is a relatively small field makes it more likely to be subject to such whims than other fields. The top general interest journals always have a macroeconomist coeditor to handle the many macro submissions, but usually get by with someone outside the field handling IO submissions. People outside the field will have a harder time selecting the papers that are most important in the field, and may be more likely to follow popular trends.

to assume that they fully understand the social processes by which some products achieve popularity. Ellison and Fudenberg (1993) builds on the Smallwood-Conlisk approach to explore whether dispersed information about product quality will be aggregated at the population level and come to be reflected in adoption decisions.

We identify two mechanisms by which such "social learning" can occur. In one information is aggregated via agents paying attention to popularity. In the other it is aggregated by geography. In both models, there are two technologies f and g. The payoffs are random variables related by $u_t^g - u_t^f = \theta + \epsilon_t$ with ϵ_t uniformly distributed on $[-\sigma, \sigma]$. Boundedly rational players observe $u_t^g - u_t^f$, but don't know the full history of payoff realizations. The popularity model looks at a homogeneous population in which there is inertia and in which players who do switch are more likely to use more popular actions: players choose g if $u_t^g - u_t^f > k(m_t(f) - m_t(g))$, where k is a positive constant and $m_t(f)$ is the market share of technology f at time t. In this model, we show that with no popularity weights ($k = 0$) both technologies get positive shares in the long run. With $k > \sigma$ there can be herding on an inferior technology. With $k = \sigma$ full learning occurs in the long run and all consumers eventually adopt the superior technology.

In the geographic model, players are arrayed on a line (which could be a physical location or a position in some social network or taste space). There is no longer a single best technology – which technology is superior depends on the location. Players observe the technology choices of those in a neighborhood around them, and also observe the average payoff of any technology used in their neighborhood. In this model, we show that social learning occurs via a geographic mechanism: the dividing point between the f-adopters and the g-adopters shifts over time and a law-of-large-numbers mechanism keeps it close to the optimum when the observation neighborhood is small. There is a tradeoff between the speed of adoption and its long-term efficiency.

Ellison and Fudenberg (1995) consider a model closely related to the nonspatial model described above. There are two primary differences: there is a random idiosyncratic component to the payoff each agent receives in each period; and we consider rules-of-thumb in which an agent asks k randomly selected members of the population about the payoffs they received in the current period and chooses the technology that provided the highest payoff in this random sample (with the proviso that an agent never adopts a technology that was used by no one in his sample.) We focus on the question of how the structure of information flows affects the learning process.

Considering first the case where the two technologies are equally good, we show that the value of k affects whether we see "herding" on one technology or "diversity" with both technologies retaining a positive market share in the long run. Intuitively, when agents rely on small samples, they are unlikely to hear about unpopular technologies, which makes it more likely that these technologies will die out. We then introduce differences in average payoffs across the technologies, and show that long-run efficient social learning will occur for a range of values of the sample size k. When k is smaller herding on an inefficient technology may be possible, and when k is larger both technologies may survive in the long run. Intuitively, there is a degree of popularity-weighting implicit in the assumption that agents don't adopt technologies not being used in their random sample, and this can support social learning as in the earlier model.

Spiegler (2004) introduces price-setting into a related model. There are N firms. Each firm has a distinct (albeit equally good) technology that provides random payoffs that are independent and identically distributed both over time and across individuals: each technology gives a payoff of one with probability α and zero with probability $1-\alpha$. There is also an $N+1$st technology that provides this same payoff at no charge. (Spiegler discusses unscientific medical practices as a potential application and refers to the firms as quacks.)

Consumers are assumed to use a rule-of-thumb that involves finding one person using each technology, treating the payoff, v_i, that person received as if it were the expected payoff of technology i, and choosing the technology for which $v_i - p_i$ is maximized. This is similar to the decision rule of Ellison and Fudenberg (1995), with the main difference being that each technology is sampled once rather than a popularity-influenced random number of times. Spiegler notes that the rule-of-thumb can also be motivated as an extreme form of Rabin's (2002) model of "believers in the law of small numbers" or as an application of a solution concept in Osborne and Rubinstein (1998).

The pricing game between the firms turns out to have an unique mixed strategy Nash equilibrium (not unlike the equilibria one sees in search-based models of price dispersion). In this equilibrium, expected prices are inversely related to the common product quality. Industry profits are nonmonotone in the number of firms. Industry profits initially increase in N because there is more likelihood that consumers' samples will contain at least one firm success, but decline as N becomes large because the price competition becomes more intense.

5.2 Models of sales

The classic models of sales by Varian (1980) and Sobel (1984) are described by their authors as rational models. The papers could also have been sold as boundedly rational or behavioral: Varian's model features some 'high search cost' consumers who are ignorant of the prices each store offers and end up going to one store chosen at random; and Sobel's features some infinitely impatient consumers who buy immediately regardless of the potential gain from waiting for a good to go on sale. In each case, a very rough intuition for why there are sales is that firms want to price discriminate and give discounts to the more sophisticated shoppers.

Rubinstein (1993) and Piccione and Rubinstein (2003) develop formal approaches to modeling cognitive abilities and use these frameworks to provide models of sales in which the discounts-for-sophisticated-consumers intuition is more formally grounded. In Rubinstein (1993), cognitive complexity is captured by the order of the "perceptron" needed to implement a strategy. Some agents can only implement very simple strategies (buying if price is above a threshold), whereas others can implement nonmonotone strategies involving two or more cutoffs. He writes down a model in which a monopolist wants to charge high-cognitive-ability agents a lower price in some states, and in which the monopolist can achieve this by randomly choosing prices in a manner that makes it unprofitable for low cognitive-ability customers to also buy in this state. Piccione and Rubinstein (2003) introduce an alternate form of differential cognitive ability: they assume that agents differ in the length m of the price history they can recall. They again consider an environment in which the firm would like to charge high-cognitive-ability agents a lower price, and show how this can be done by alternating between regular and sale prices in a manner that high-ability agents can recognize (letting them buy only when the item is on sale) and low ability agents cannot (forcing them to pay the time-average price).

Kahnemann, Knetsch, and Thaler (1986) had much earlier proposed that sales might have a different irrational origin. They conduct a survey, and find that many subjects say that it is "unfair" for firms to raise prices when demand goes up and speculate that this may give firms an incentive to hold sales rather than reducing "regular" prices: if firms lower regular prices when demand is low, they will be branded as unfair if they raise prices back to normal when demand returns to normal. Rotemberg (2005) proposes a more complex fairness-based model to account both for firms' occasional use of sales and for the stickiness of prices within and across non-sale periods. In his model, consumers have reciprocal-altruism preferences and punish firms discontinously if their estimate of the firm's altruism crosses a threshold. The model also relies on the firms' objective function being a concave function of profits and on consumers feeling regret. He argues that similar assumptions can also help explain how firms adjust prices in response to demand shocks and inflation.

5.3 Price dispersion

The IO literature developed a number of search-cost based explanations for price discrimination in the early 1980s.[6] These models are compelling for many real-world applications, but Baye and Morgan (2004) note that dispersion seems to occur even in enviroments where it is less plausible that substantial search costs exist: it is common for products listed for sale on Internet price search engines; and it even occurs in laboratory experiments in which a computer plays the buyer's role to perfectly recreate a Bertrand duopoly.[7]

Baye and Morgan propose that one reason why this occurs may be that the equilibrium of the Bertrand competition game is somewhat nonrobust to departures from rationality. Suppose that firms are ϵ-optimizers rather than being fully rational, *i.e.* they may pick any action that earns profits that are within ϵ of the maximum possible profit. One might

[6]Baye and Morgan (2004) provide an excellent survey.
[7]See Dufwenberg and Gneezy (2000).

think at first that the Bertrand model is fairly robust to such a change because in any *pure strategy* ϵ-equilibrium industry profits would be at most ϵ. Baye and Morgan note, however, the Bertrand game also has mixed strategy ϵ-equilibria with much higher profits. For example, for any $x \in (0, \pi^m)$, suppose firms use the mixed strategy with CDF

$$F^x(p) = \begin{cases} 0 & \text{if } p < \underline{p} \\ 1 - x/pD(p) & \text{if } p \in [\underline{p}, p^m) \\ 1 & \text{if } p \geq p^m \end{cases}$$

where $\underline{p}$ is such that $\underline{p}D(\underline{p}) = x$. In the Bertrand duopoly game with zero costs, the maximum gain from deviating from this profile is $x^2/2\pi^m$. If we set this to ϵ, we find that a firm can earn at least $\sqrt{2\epsilon\pi^m} - \epsilon$ in an ϵ-equilibrium. This is a strikingly large number for reasonable values of ϵ. For example, if ϵ is one percent of the monopoly profit, the aggregate industry-profits in and ϵ-equilibrium can be approximately 26% of the monopoly profit.[8]

5.4 Obfuscation

One of the most basic results on the economics of information disclosure, is that firms will disclose all relevant information to consumers if the information is costless to disclose and disclosures are credible (either because the facts are evident or because truth-in-advertising laws provide a guarantee)(Grossman 1981; Milgrom 1981). The simple intuition is that the firm with the highest possible quality will always want to disclose its information to increase consumers' willingness to pay. Given that the best-news firm is disclosing its information, the firm with the next best news will also gain from separating from any firms that are pooling on nondisclosure, and so on.

Ellison and Ellison (2005) note that there are big differences between this theoretical prediction and what we see in many real-world environments. For example, mattress manufacturers put different model names on products sold through different stores and provide sufficiently few technical specifications so as to make it very difficult to compare prices across stores. Credit cards are another good example: it is also hard to imagine that the

[8] Note, however, that the play is ϵ-suboptimal only in an *ex ante* sense. When the realization of the randomization calls for setting $p = p^m$, play is $O(\sqrt{\epsilon})$ inefficient in an *ex post* sense.

complex fee schedules in small print on the back of credit card offers could not be made simpler. Our empirical work examines a group of small retailers selling computer parts over the Internet via the PriceWatch search engine. The most basic observation of the paper is that many of the firms have clearly adopted pricing practices that make it time-consuming and difficult for consumers to understand what exactly a firm is offering and at what price. For example, products are described incompletely and consumers may have to go through many pages to learn all of nonstandard aspects of the offer: the restocking fee that will apply if the product is returned, how much extra the consumer will need to pay for a warranty, etc. A second interesting empirical observation is that retailers appear to obtain substantial markups over marginal cost even though there is easy entry, minimal product differentiation, and minimal inherent search costs.

The combination of these two facts – there appears to be a great deal of obfuscation; and obfuscation appears to affect markups – makes obfuscation a natural topic for IO economists to study. The emphasis of the current IO literature on product differentiation as the source of markups may well be fully justified empirically, but another reason for the absence of any mention of obfuscation in Tirole (1988) may be that it would have been an awkward topic to discuss in the rational paradigm.

The most straightforward way to think about obfuscation using standard IO tools would be to regard it as increasing search costs in a model with costly search like Stahl (1989). One would want, however, to extend the standard models to allow the search costs to vary by firm (instead of just across consumers). Even then, we would have a fairly black-box model. A nicer bounded rationality augmentation would be to derive search costs as a special case of costly computation.

More direct bounded rationality approaches are also appealing. Gabaix and Laibson (2004) suggest a very simple formalization: one could regard obfuscation as increasing the variance of the random evaluation error ϵ_i in a model in which consumers have noisy estimates of the utility they will receive from consuming a product: they think they will get utility $\delta_i + \epsilon_i$ from consuming product i when they actually get utility δ_i. Such a model is formally equivalent (from the firm's perspective) to a model in which firms can invest in product differentiation. Firms will invest in obfuscation just as they invest in differention to raise markups. The equilibrium markups for a given error distribution can be derived as in Perloff and Salop (1985).[9] Gabaix and Laibson derive new results on the asymptotic rate at which markups decline as the number of firms increases, and emphasize that for some error distributions adding firms to the market will drive down prices very slowly.

Spiegler (2006) discusses another rule-of-thumb model. In his model, products inherently have a large number of dimensions. Boundedly rational consumers evaluate products on one randomly chosen dimension and buy the product that scores most highly on this dimension. In this model, consumers would evaluate the products correctly if products were designed to be equally good on all dimensions. Spiegler shows that this will not happen, however. Essentially, firms randomize across dimensions making the product very good on some dimensions and not so good on others. He thinks of this cross-dimensional variation as intentional obfuscation. The comparative statics of the model may help us understand why there is more obfuscation in some markets than in others: obfuscation increases when there are more firms in the market, and when the outside option is more attractive.

5.5 Add-on pricing

In many industries, it is common to sell high-priced add-ons. Hotels charge high prices for dry cleaning, telephone calls, minibar items, and restaurant meals. Credit cards have high late-payment fees. Upgrading to a larger hard drive and adding more memory adds substantially to the advertised price of a Dell computer.

Ellison (2005) notes that we can think of high add-on prices in a couple ways. One is that we may simply be seeing the outcome of a standard multi-good price discrimination model. Suppose that consumers who are more price-sensitive when choosing between firms ("cheapskates") also have a lower willingness to pay for quality-improving add-on.[10] Then,

[9] Perloff and Salop is an exception to my earlier remark about departures from rationality in 1980's IO papers being unintended or unwanted. They have a brief section in the back of their paper noting that the ϵ's in their model could capture " 'spurious' as well as actual product differentiation". They mention Chamberlin and Galbraith as among those who had previously discussed spurious differentiation and point to blind taste tests as providing empirical support for its importance.

[10] I would argue that this assumption is the most natural one to make. Note, however, that it does differ from what is assumed in most papers discussed in Armstrong (2006) and Stole (2005). The standard assumption has been that brand preferences and quality preferences are independent.

in a standard imperfect competition/price discrimination model in which firms simultaneously announce prices for low- and high-quality goods and all consumers are perfectly informed and rational, firms will charge higher markups on higher quality goods.

A second way to think about high prices for add-ons is as in Lal and Matutes (1994). If add-on prices are not observed by consumers when choosing between firms, then add-ons will always be priced at the ex post monopoly price.[11] In such a model, of course, the profits earned on the add-on may be competed away in the form of lower base-good price. Lal and Matutes's "loss leader" model is an example in which the price cut on base good exactly offsets the profits earned on the add-on. The second main observation of Ellison (2005) is that this no longer holds in models with cheapskates. In such an environment, firms that rely on sales of add-ons for a large part of their profits face a severe adverse selection problem: price cuts disproportionately attract cheapskates who don't buy add-ons. This adverse selection problem discourages price-cutting. As a result, the joint adoption of add-on practices raises equlibrium profits.

An interesting question raised by the profitability of the joint adoption of add-on pricing in this second conceptualization is whether it is individually rational for firms to adopt add-on pricing. Typically, consumers would be able to buy a more efficient bundle if add-ons were priced closer to cost. If firms could commit to setting such prices and costlessly inform consumers via advertising, then firms in a rational-consumer model would typically want to do this.[12] Hence, advertising costs, tacit collusion, or some other modification is needed to account for why add-on pricing is practiced.[13]

Gabaix and Laibson (2005) develop a boundedly rational explanation for why add-on prices often are not advertised. Proceeding along lines suggested in Ellison (2005), they develop a model with two types of consumers: rational consumers and irrational consumers.

[11] Lal and Matutes explanation is a version of Diamond's (1971) classic argument about search costs leading to monopoly pricing. It can also be thought of as a version of Klemperer's (1987) switching cost model: one can think of the add-on being sold at a later date, with the inability of consumers to see add-on prices being equivalent to assuming the firm can't commit to future prices.

[12] See, for example, Shapiro (1995).

[13] Note that this only applies to the second model of why add-ons are expensive, not to the first. The price discrimination model is a standard pricing game where add-on prices are high when optimally set and observed by all consumers.

In such an environment, the profits earned serving rational consumers are increased by advertising a higher base-good price and a lower add-on price. Profits obtained by serving irrational consumers are reduced, however. They describe this reason why this occurs as the "curse of debiasing". Irrational consumers are assumed to be unaware of the add-on's existence unless they see an advertisement listing a price for it. Once informed, they realize that they can take steps to avoid purchasing the add-on. This has the effect of reducing their willingness to pay for the advertising firm's product. If the fraction of irrational consumers is sufficiently high, then the losses on them can outweigh the gains on the rational consumers.

Papers on oligopoly behavior-based price discrimination, e.g. Chen (1997) and Fudenberg and Tirole (2000), consider a similar problem. They also, however, allow consumers to buy the add-on from the firm that did not supply them with the base good (although this is inefficient). In models without commitment, add-on prices are determined by the second-period oligopoly competition. As Armstrong (2006) notes, this would make the effect of naive consumers very different. The fact that consumers don't think about second period prices until the second period won't make second period prices any higher, and would actually lower first-period prices by eliminating the effect that makes first-period behavior less sensitive to price differences. See Fudenberg and Villas-Boas (2005) for an insightful discussion of the mechanics of these models.

The paper of Spiegler (2006) I mentioned earlier can also be thought of as providing an explanation for add-on prices. One can think of the differences in product quality on different dimensions as representing both pure quality differences and differences in add-on fees charged in various circumstances.

5.6 Performance standards

How well an individual or firm has performed (or will perform) typically has a multidimensional answer. Performance assessments, however, often ultimately result in a zero or one decision. Should a student be admitted to this college? Should a student be given an A or a B? Should a job applicant be hired? Should a paper be published? Should a professor be granted tenure? These decisions establish performance standards. Two questions about standards are of primary interest: how will multiple dimensions be weighted and how high will the overall hurdle be?

In some applications, one could try to develop fully rational models of performance standards, e.g. a firm should hire a worker if and only if the firm's profits are higher with the worker than without. In many other applications, no clear objective function is available, e.g. are colleges supposed to admit the students who will perform best in classes, those who will add most to campus life, those who will benefit most from the education, those who will go on to accomplish great things, or those who will eventually donate the most money to the college? Even when there is a clear objective, I would argue that the fully rational model is usually implausible because judges will typically lack the understanding necessary to maximize the objective, e.g. a firm will not know how a student's GPA in math classes and her experience at the school newspaper determine her incremental contribution to the firm's profits. As a result, the way that many such decisions are made is to compare the current candidate with past candidates, and to use relative performance to judge whether to admit the candidate.

Sobel (2000, 2001) uses a rule-of-thumb approach to explore how various factors affect whether standards tend to rise or fall. In these papers, candidates are assumed to choose a level of costly effort and to direct this effort to achieve a multidimensional vector of accomplishments. In the two-dimensional case, for example, the candidate's achievements are described by a pair (q, r). Candidates are then judged relative to the pool of recent successful candidates.

In Sobel (2000) the way the judging is done is that a single judge aggregates the multiple dimensions using a function $v(q, r)$, and deems the t^{th} candidate successful if $v(q_t, r_t) \geq z_t$. It is assumed that the standard z_t is set so that a fraction τ of the previously successful candidates would meet the standard. When the function v is held fixed and there is no randomness in the achievement process, this model predicts a bunching of performance. Starting from any initial condition, candidates who are able to do so exert exactly the effort necessary to achieve the $1 - \tau^{th}$ percentile level of performance, and eventually the entire pool of recent sucessful candidates has achieved exactly this performance level. The most interesting results concern what happens when weighting functions change over time, e.g. shifting from v to v' and back to v again. Such shifts cause standards to decline. Intuitively, when standards shift from v to v', the performance level of the earlier candidates (measured in terms of v') can be achieved at lower cost by tailoring effort to v'. Hence, equilibrium effort declines. When the standards shift back to v, candidates can again achieve a performance that grades as highly as the performance of the candidates who had worked toward v' with less effort. Comparing the first and third cohorts of agents, performance will have unambiguously declined.

Sobel (2001) considers institutions involving voting by a panel of judges. Each judge has a different v function. As in the earlier paper, judges vote to acceept a candidate if the candidate's performance is in the top τ of recent successful candidates. What happens in this model depends both on the voting rules and the dimensionality of the performance space. When votes from only a small fraction of the judges are sufficient for admission, standards decline. When near unanimity is required, standards increase over time. In intermediate cases the results are more nuanced.

Ellison (2002) focuses on the weighting of different dimensions rather than the overall level of the standard. It is motivated by changes in the standards of academic journals over the last thirty years. There are several clear trends in economics (and other fields) over that period: papers have been getting longer; they have longer introductions, more references and discuss more extensions; authors are required to carry out more extensive revisions before papers are published. I argue that all of these changes can be thought of as reflecting a shift in quality standards. Think of an academic paper as having a two-dimensional quality (q, r), where q reflects the importance of a paper's main contributions and r reflects other dimensions that can be improved with incremental effort, e.g. improving the exposition, generalizing and extending results, and performing robustness tests. The observed trends can be thought of as caused by or reflecting an increased weight being placed on r-quality, *i.e.* if articles are judged acceptable if $v(q,r) = \alpha q + (1-\alpha)r \geq z$, then we may be seeing a decrease in α.

One way to account for such a trend would be to use the comparative statics of a rational model in which α is chosen to optimize some social welfare function. One can compute how the distribution of paper qualities is affected by α in equilibrium, and one could argue that the distribution produced by a lower α is now preferable because of some exogenous change in the profession. Such changes are hard to identify, however, and it is also hard to find any evidence that changes in standards were intentional. This motivates the search for explanations in which the shift is an unconscious byproduct of rule-of-thumb behavior.

My model focuses on the behavior of referees. Referees are assumed to try to faithfully apply the profession's standards (rather than imposing their own preferences over quality dimensions). They do not, however, inherently know what values of (α, z) to apply. They try to learn these by seeing what parameters best fit the data they get in the form of seeing decisions made on papers they refereed, seeing papers in journals, and seeing decisions on their own papers. In each period authors work to maximize their chance of acceptance given their current understanding of the norm, referees apply the standard they currently believe in, editors accept the fraction τ of papers that referees rate most highly, and beliefs are updated given the acceptance decisions.

When referees are unbiased, this model has a continuum of equlibria. Given any weight α, there is a corresponding achievement level $z(\alpha)$ that yields an equilibrium. I then introduce a small behavioral perturbation, combining the rule-of-thumb and psychology-and-economics approaches. Players are assumed to be overconfident about the quality of their own work and think that it is ϵ higher in quality than it truly is. This destabilizes the former equilibria: players will be puzzled about why it is that their papers are being rejected. The first effect that this would have on players is to make them think that z must be higher than they had thought. This hypothesis, however, also cannot fully explain the data: it cannot account for why marginal papers by others are being accepted. The result of players' continuing struggles to reconcile inherently contradictory data is a slow, gradual evolution of beliefs about the social norm in the direction of decreasing α. At the most abstract level, the idea of the paper is that one way to explain a long trend is to perturb a model with a continuum of equilibria. A slight perturbation of such a model can have a unique equilibrium and the disequilibrium dynamics can feature a slow evolution along the near equilibrium set.

6 The New Behavioral IO: Biases from Psychology and Economics

The recent surge of interest in bounded rationality in industrial organization comes on the heels of a bigger and slightly less recent surge of interest in psychology and economics. This literature has by now documented a plethora of ways in which real consumers depart from the rational self-interested ideal: they discount in a nonexponential manner, exhibit loss aversion; care about fairness; have self-serving biases; fail to update in a fully Bayesian manner, etc. More importantly, it has developed a number of simple models that can be adopted as representations of agents subject to such biases. Exactly how portable such models are is subject to debate, but at least in principle one can construct the behavioral-bias counterpart of a given rational model by replacing the utility maximization assumption with the assumptions of one's favorite representation of consumers subject to this behavioral bias.

The initial papers in this branch of the behavioral IO literature have tended to focus on how firms will choose prices and product characteristics to exploit behavioral biases and whether competition will eliminate the exploitation. Combining the IO and psychology and economics literatures, however, naturally gives many more than just one paper topic per bias – we can get a whole matrix of paper topics. Think of the set of behavioral biases as the column headings, and put all of the standard models in IO as the row headings: how will a monopolist price, how will a monopolist selling durable goods price; how will a monopolist price discriminate; how will oligopolists selling differentiated goods set prices; how will some action be distorted to deter or accomodate entry, etc. It takes little knowledge or imagination to come up with literally thousands of paper topics: Tirole's (1988) text has hundreds of IO models, each of which could be combined with dozens of behavioral-bias models.

	Hyperbolic Discounting	Loss Aversion	Fairness	Self-Serving	Imperfect Bayesian
Monopoly pricing	DellaVigna Malmendier	Heidhues-Koszegi	Rotemberg		
Price discrimination					
Durable goods					
Static oligopoly					
Dynamic oligopoly					
Entry deterrence					
Innovation					

Will this lead to thousands of behavioral IO papers in the next few years? I am pretty sure (and hope) the answer is no. The problem is that most combinations will not produce observations that are sufficiently deep or interesting to warrant their being published. For example, Hossain and Morgan (2006) conduct field experiments on eBay and find that auctioning goods with a high (but not too high) shipping charge raises more revenue than using an equivalent minimum bid and making shipping free. It's a striking fact and they've written a very nice psychology and economics paper around it that discusses how the results can be explained by mental accounts with loss aversion (or other explanations). The companion how-should-firms-price paper, in contrast, is too obvious to write: if consumers behave this way then firms should use high shipping charges.

I would argue, nonetheless, that most boxes in this matrix are worth exploring. Without doing so, it is hard to know whether they will yield interesting alternate explanations for previously noted phenomena, provide potential explanations for facts about particular industries that are hard to square with existing models, or help us think about when consumer irrationality does and doesnt matter.

In this section I'll discuss two behavioral IO papers that build on the psychology and economics literature. Each belongs to the monopoly pricing and bias X row of my matrix. I will then discuss some general lessons.

6.1 Monopoly pricing with hyperbolic discounting

Della Vigna and Malmendier's (2004, 2005) work on selling goods with delayed benefits (or delayed costs) to time-inconsistent consumers nicely exhibits the potential of behavioral IO. Their motivating example is pricing at health clubs: they think of consumers as incurring a short-run disutility when visiting a club, and enjoying a delayed reward in the form of better health.

The model uses a theoretically appealing (and practically relevant) degree of generality in pricing. Consumers are initially offered a two-part tariff with an upfront payment of L and an additional per visit charge of p. If consumers accept this offer, they learn the disutility d that they will incur if they visit the club, and then decide whether to visit (which costs p and gives a delayed benefit b.) Note that the decision to accept the two-part tariff is made under symmetric information, so in a rational model the health club would extract all consumer surplus via the fixed fee.

Consumers are assumed to have (β, δ) quasi-hyperbolic discounting preferences: from the perspective of period 0, payoffs in period t are discounted by $\beta\delta^t$. They consider both naive hyperbolic consumers who don't realize that they have a commitment problem, and sophisticated hyperbolic consumers who are fully aware of their time inconsistency.

In this model, one can think of two reasons why a health club will want to distort p away from marginal cost. First, sophisticated rational consumers would like to commit themselves to go to the health club more often. The health club can help them to do this by setting p below cost. Second, naive rational consumers will overestimate the number of times that they will go to the club. Reducing p and increasing L widens the gap between the surplus that the consumer expects to receive from accepting the contract and what the consumer actually receives. Hence, distorting the contract in this way makes the contract more appealing to these consumers. The two effects go in the same direction, so regardless of what type of hyperbolic consumers we have, we reach the same conclusion: visits will be priced below marginal cost.

Is this distortion bad? In the case of sophisticated consumers it is not. Essentially, one can view the health club as selling a commitment device that allows the consumer to overcome his or her self-control problem and achieve the first-best. In the case of naive hyperbolic consumers things are less clear cut. The low per-visit price does get consumers to visit the gym more often than they would with marginal cost pricing. Consumers' misperception of the value they will get from the contract, however, leads to their receiving negative total surplus.

One notable limitation of Della Vigna and Malmendier's work is that consumers are assumed to be *ex ante* homogeneous. This makes the paper less complete as an applied model – it can't explain why real-world health clubs offer a menu of contracts – and also eliminates any possible insights that might come from analyzing conflicts between rent extraction and surplus maximization.

Della Vigna and Malmendier's (2005) empirical study lends credence to the view that time-inconsistency is an important factor in health-club pricing. The health clubs they surveyed offer contracts in which the per-visit charge is set below marginal cost, and most consumers take them. In fact, they take these two-part tariffs even though the clubs also offer contracts with a higher per-visit charge that would be cheaper for most consumers. Clearly, people either must value the commitment or must overestimate their future usage. Survey data suggest that overestimation is at least part of the story.

6.2 Monopoly pricing with loss aversion

Heidhues and Koszegi (2004) explore pricing to consumers who experience loss aversion.[14] The formal specification of consumer behavior follows Koszegi-Rabin (2005). Consumers have reference-dependent utility functions that depend not only on the number of units x of the good they consume and on the amount of money m they have left over, but also on reference levels r_x and r_m which are their ex ante expectations: $u_t(x, m; r_x, r_m) = xv_t + m + \mu(x - r_x) + \mu(m - r_m)$. Loss aversion comes in via the function μ, which is assumed to be have a kink at the origin. Note that consumers feel a loss both if they are unable to buy a product they expected to buy and if they pay more than they expected to pay.

[14]Schlag (2004) is another paper examining pricing to boundedly rational consumers. His consumers follow a regret-minimization strategy.

Heidhues and Koszegi consider a world in which demand and cost are both random and time-varying. In the base model, firms are assumed to be able to commit to a distribution of prices. Some interesting effects arise because this commitment allows the firm to manage consumer expectations. One observation is that prices will be sticky and firms may set a constant price (or choose prices from a discrete set) even when cost shocks are continuously distributed. The disutility that loss-averse consumers feel when they pay more than they were expecting is greater than the utility they derive from paying symmetrically less than they were expecting. This provides an incentive to keep prices constant. A related observation is that markups are countercyclical. Another fundamental conclusion is that there is substantial scope for indeterminacy: as in Koszegi-Rabin (2005) the purchase decision contingent on the price is not necessarily unique because the consumer has a higher valuation when he expects to buy, and even apart from this there can be multiple pricing equilibria when the firm lacks commitment power.

6.3 Some thoughts

In this section I discuss some basic principles relating to how firms "distort" pricing to exploit behavioral biases and some challenges that the psychology and economics motivated literature will face going forward.

6.3.1 Will monopolists exploit biases?

Consider a standard quality-selection problem as in Spence (1975). Suppose that there is a population of consumers with unit demands. A consumer of type θ is willing to pay at most $v(s;\theta)$ to obtain one unit of a good of quality s. Assume θ is uniformly distributed on $[0,1]$ and that $\partial v/\partial\theta < 0$ so that if q units are sold then the consumers will be those with $\theta \in [0,q]$.

Suppose that a monopolist that must choose a single quality level s for its product. Assume that the good is produced under constant returns to scale, with a quality s good having a unit production cost $c(s)$. The monopolist's problem is

$$\max_{q,s,p} \quad q(p - c(s))$$

$$s.t. \qquad v(s;\theta) - p \geq 0 \;\text{ for all } \theta \in [0, q]$$

Conditional on the quantity sold being q and the quality being s, the highest price that can be charged is $v(s;q)$, so this reduces to

$$\max_{q,s} \; q(v(s;q) - c(s))$$

The first-order condition for the monopolist's quality choice s^m is

$$\frac{\partial c}{\partial s}(s^m) = \frac{\partial v}{\partial s}(s^m, q^m).$$

The marginal cost of providing higher quality is equal to the marginal benefit for the marginal consumer.

The social planner's problem would be

$$\max_{q,s} \int_{\theta=0}^{q} v(s;\theta)d\theta - qc(s).$$

The first order condition for the first-best quality choice s^{FB} is

$$\frac{\partial c}{\partial s}(s^{FB}) = \frac{1}{q^{FB}} \int_{\theta=0}^{q^{FB}} \frac{\partial v}{\partial s}(s^{FB}, \theta)d\theta.$$

The marginal cost of providing higher quality is equal to the marginal benefit for the average consumer.

Spence emphasized that monopolists typically will not provide optimal quality: the marginal and average consumer can have different valuations for quality; and the pool of customers served by the monopolist differs from the pool the social planner would want to serve. One case in which the monopolist's quality choice is optimal, however, is when the population is homogeneous. In this case, both the monopolist and the social planner will serve all consumers and there is no difference between the marginal and average consumer. Hence, the monopolist provides optimal quality.

The quality-selection model is relevant to the question of how firms respond to behavioral biases because one can regard many decisions a monopolist makes as quality choices. For example, in Della Vigna and Malmendier's health-club application, the per-visit charge a health club imposes is a product characteristic that determines the quality of a club membership. A contract with a lower per-visit fee is a higher quality product.

The optimal quality result of Spence's model implies that a monopolist facing an *ex ante* homogenous unit-demand customer population will choose to sell the product s that maximizes $v(s) - c(s)$. When I developed the model I said $v(s;\theta)$ was the willingness to pay of the type θ consumer. In a rational model this is the amount of money that offsets the utility the consumer receives from consuming the product. Spences result applies equally well in irrational models, however. One just has to keep in mind that the appropriate $v(s)$ is the willingness to pay for a quality s good at the moment at which the consumer makes the purchase decision.

In Della Vigna and Malmendier's sophisticated hyperbolic model, just like in the rational model, the willingness to pay of the time-zero agent is the expected utility that the time-zero consumer receives (in equilibrium) if she signs up for the health club. Hence, the outcome is that the health club chooses the contract that is optimal for the time-zero agent. In a naive hyperbolic model, willingness to pay is the time-zero agent's (incorrect) forecast of his equilibrium utility. Hence, the contract is also designed to increase the difference between the forecast utility and the true utility.

The same basic intuition will apply to other behavioral biases: monopolists will distort product characteristics along whatever dimensions increase irrational consumers' willingness-to-pay. What these distortions are under alternate behavioral specifications, of course, still needs to be worked out. What makes Della Vigna and Malmendier (2004) successful is not that it shows that a monopolist will exploit boundedly rational consumers, but rather that the exploitation is a compelling explanation for something we see in the world (low per visit fees). A challenge for future authors is to find other applications where exploitation takes an interesting form.

6.3.2 Does competition eliminate exploitation?

Another question that behavioral economists have raised is whether competition eliminates the exploitation of behavioral biases. The question can be asked either in the imperfect competition models that are common in industrial organization or in a perfect competition framework.

In the homogeneous population case, the answer is obviously no. Competitive firms will behave just like monopolists and make product-design choices s so as to maximize $v(s) - c(s)$. The only difference is that the surplus will be returned to consumers in the form of lower fixed fees.

In heterogeneous population models, the precise choices of monopolists and competitive firms will differ. How this will work depends on whether firms are or are not assumed to be able to offer multiple quality levels.

For some applications one would want to suppose that only a single quality level will be produced. The monopolist will design its product to appeal to its marginal consumer. Firms engaged in imperfect competition a la Hotelling will design their products to appeal to the consumer who is on the margin between the two firms. Although the monopoly and competitive product designs will be different because the marginal consumers are different, one imagines that qualitative conclusions about the direction in which product designs are distorted will usually be similar.

For other applications it will be better to assume that firms can introduce multiple products at different quality levels and use them to price discriminate. In a monopoly model, the type $\overline{\theta}$ with the highest willingness to pay is typically sold a product of the "optimal" quality, which here means maximizing $v(s; \overline{\theta}) - c(s)$. Other types will be sold products of quality lower than that which maximizes $v(s; \theta) - c(s)$. Whether this adds to or offsets the distortion that comes from exploiting the difference between v and utility will depend on the application. In competitive price discrimination models, the pattern of quality distortions depends on the joint distribution of preferences for quality and preferences for firm 1 versus firm 2. Hence, comparisons with the monopoly case will depend on how preference heterogeneity is specified.

7 Concluding Remarks

In this essay I've tried to give some perspective on the burgeoning field of boundedly rational industrial organization. It's a hard literature to summarize because one can depart from rationality in so many ways. The irrational actors can be the firms or the consumers.

Several approaches to modeling irrationality can be taken: one can specify rules of thumb, behavior can be derived as the maximizer of something other than utility/profits; or one can explicitly introduce cognitive bounds. I've stressed two advantages of boundedly rational approaches: boundedly rational behavior seems more realistic in some applications; and the tractability of boundedly rational models can sometimes allow researchers to incorporate additional features into a model. For the next few years at least there is probably also a third important advantage: after twenty-five years of focusing on rational models, the questions rational models are best suited to address have been much more thoroughly explored than questions best addressed in boundedly rational models.

I've noted that the current literature on boundedly rational industrial organizaiton seems to be proceeding along two different branches. One easy way to give advice for the literature is to suggest that each branch adopt attractive features of the other. In many papers in the IO branch, the particular form of the departures from rationality is motivated by little more than the author's intuition that the departure is plausible. More reliance on empirical and experimental evidence could be a significant improvement. A relative weakness of the psychology and economics branch is that the papers are less informed by the existing IO literature on the topic and don't live up to existing IO norms in terms of incorporating consumer heterogeneity, imperfect competition, price discrimination, etc.

Which of the branches of boundedly rational IO is likely to be most successful in the coming years? Let me say first that I think in the long run the two branches will come together. Until they do, I think that having both is valuable. My answer to the question of which will be more successful in the next few years depends on the meaning of successful. If successful means advancing the IO literature I think the answer is the first branch. Delving into the IO literature and focusing on topics where the existing explanations are lacking is the most efficient way to improve a literature. If success is measured by publications or citations, I think the answer is the second branch. I noted earlier that an attractive feature of the psychology and economics literature is that the models developed in papers like Laibson (1997), Fehr and Schmidt (1999), and Eyster and Rabin (2005) are mechanically very much like rationality and can be grafted into just about any model. This creates many obvious opportunities for making contributions. When these opportunities do yield insights they should be easy to publish: the mechanics of these models make it easy to fill out an idea into a 35 page paper containing the kinds of fixed-point calculations referees are used to seeing.

To conclude, I'd like to make one last set of remarks on the shift that has taken place from focusing on irrational firms to focusing on irrational consumers. For many reasons this is very appealing. There is a great deal of experimental evidence on consumer behavioral biases. Firms can hire consultants to advise them on how to maximize profits and market competition may tend to eliminate firms that don't maximize profits. I agree with all these points, but nonetheless think there are good reasons to keep the boundedly-rational firm literature alive too.

Slight departures from traditional assumptions about consumer rationality can have a very large impact on economic models. Diamond's (1971) search model is a striking example in which prices go all the way from the competitive level to the monopoly level if consumers have an ϵ search cost. The evolving standards model of Ellison (2002) is another example how an ϵ behavioral bias can have a big impact. In other models, however, this sensitivity is not there: if all consumers ϵ-optimize or an ϵ fraction of consumers are irrational, then there will just be an $O(\epsilon)$ shift in firm strategies.

I noted above that Baye and Morgan (2005) have shown that outcome of the Bertrand competition game is quite sensitive to whether firms are ϵ-optimizers. Although the mixed equilibrium they exhibit immediately strikes one as being a very special feature of this particular game, it is not clear that the sensitivity they are showing is at all unusual. As Akerlof and Yellen (1985) have noted, in smooth models, the derivative of a firm's profits with respect to its action is zero at the Nash equilibrium. If a firm changes its action by ϵ, profits will be within ϵ^2 of the best-response profits. A change in one firm's action does have a first-order effect on consumers and on the other firms' profits. Hence, in an ϵ-equilibrium, profits can be of order $\sqrt{\epsilon}$. For example, the simplest Cournot duopoly with $D(p) = 1 - p$ and zero costs any (q_1, q_2) with $q_i \in [1/3 - 2\sqrt{\epsilon}/3, 1/3 + 2\sqrt{\epsilon}/3]$ is an ϵ-equilibrium. This includes the monopoly outcome if $\epsilon > 1/64$, which is approximately 6% of the monopoly profit level. In such examples, small departures from rationality on the part of firms can be as important as much larger departures from rationality on the part of consumers.

I look forward to seeing the literature on boundedly rational IO develop in the years to come.

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