AVI GOLDFARB and BOTAO YANG*

Some managers are better than others. Using the cognitive hierarchy framework of Camerer, Ho, and Chong (2004), the authors develop a structural econometric model that estimates the level of strategic thinking. In the model, firms with a high level of strategic thinking are more likely to correctly conjecture the expected actions of their competitors. The authors apply this model to decisions by managers at 2233 Internet service providers of whether to offer their customers access through 56K modems in 1997. The model is validated by showing that firms with a higher estimated probability of strategic thinking were more likely to have survived through April 2007. The estimation results show considerable heterogeneity in the degree to which firms behave strategically and suggest that strategic ability affects marketing outcomes; specifically, a simulated increase in strategic ability means that fewer firms offer the technology to their customers.

Keywords: behavioral game theory, empirical industrial organization, technology diffusion, Internet service providers, cognitive hierarchy

Are All Managers Created Equal?

Some managers are better than others. This (perhaps unsurprising) statement is implicit in the teaching of business students and the widespread reporting of good and bad managerial decisions. To better understand how management ability affects outcomes, it is necessary to allow for heterogeneity in ability in models. Nevertheless, although several studies model heterogeneous consumers on a variety of dimensions, management heterogeneity is rarely examined. This is not for a lack of models of strategic heterogeneity. For example, Camerer, Ho, and Chong (2004) develop a “cognitive hierarchy” model (hereinafter, CH model) of heterogeneous strategic thinking in which players differ in how deeply they consider competitor choices.[1] They also provide considerable supporting evidence from laboratory experiments. In this article, we develop the first structural nonlaboratory estimate of management heterogeneity based on the CH model and apply it to the decisions of 2233 Internet service providers (ISPs) to provide 56K modem technology to their customers. Using evidence from laboratory experiments, we build an empirical model in which players differ in their ability to correctly conjecture the behavior of their competitors. We then explore the consequences of a change in this ability for ISPs and for modem manufacturers.

Heterogeneity in strategic ability is particularly important in retail markets such as the ISP market. Retailers must choose which products to offer their customers, and the benefit of offering a particular product depends on whether competing retailers also offer that product. Thus, optimal product assortment decisions are dependent on expectations over competitor actions. Strategic thinking by retailers will then also affect manufacturers. Ataman, Mela, and Van Heerde (2008) show that wide distribution may be the most important factor in determining the success of a new product. Thus, if strategic ability affects retailer decisions to offer products, it will affect manufacturer outcomes as well.

---

*Avi Goldfarb is Associate Professor of Marketing (e-mail: agoldfarb@rotman.utoronto.ca), and Botao Yang is a doctoral student in Marketing (e-mail: botao.yang04@rotman.utoronto.ca), Rotman School of Management, University of Toronto. The authors are listed alphabetically. The authors thank Marc Rysman and Shane Greenstein for generously providing the data and Amitai Alter, Pat Bajari, Tat Chan, Andrew Ching, Allan Collard-Wexler, Shane Greenstein, Ernan Haruvy, Teck Ho, Noah Lim, Mike Mazzeo, Jeff Prince, Sanjog Misra, Sridhar Moorthy, Brian Ratchford, Mengze Shi, David Soberman, Junji Xiao, and Yupin Yang, as well as seminar participants at Washington University, University of Arizona, University of Chicago, University of Illinois at Urbana–Champaign, University of Texas at Dallas, Stanford, University of California, Los Angeles, the 2008 Winter Meetings of the Econometric Society, the University of Toronto, and the 2007 International Industrial Organization Conference for helpful comments. This research was partially supported by Social Sciences and Humanities Research Council Grant No. 538-02-1013. All opinions and errors are the authors alone. Teck Ho served as associate editor for this article.

[1] Haruvy, Stahl, and Wilson (2001) and Ho, Lim, and Camerer (2006), among others, discuss several other behavioral economic models of player heterogeneity, such as McKelvey and Palfrey’s (1995) quantal response equilibrium.

ISSN: 0022-2437 (print), 1547-7193 (electronic)

Journal of Marketing Research
Vol. XLVI (October 2009), 612–622

In this article, we explore a particular kind of strategic ability—namely, the ability to correctly conjecture competitor actions through step-by-step reasoning. A rich experimental literature has found that the cognitive requirements of finding a perfect Bayesian equilibrium are substantial (for a review, see Camerer 2003). These studies show that rather than solving for the equilibrium, players typically go through a small (and varying) number of iterations on the expected actions of other players (e.g., Costa-Gomes and Crawford 2006; Stahl and Wilson 1994). Overall, the experimental evidence on the difficulty of playing these games suggests that small firms with inexperienced managers in a new industry are unlikely to fully solve for the perfect Bayesian equilibrium. Because we are studying such an industry, we adapt Camerer, Ho, and Chong's (2004) CH model to the strategic decisions of ISPs. We operationalize this by modeling a Type 0 retailer to act as if it is the only player in the market. A Type 1 retailer acts as if it believes that all other retailers act as if they are the only player in the market. A Type 2 retailer acts as if all other players are distributed between Type 0 and Type 1. A Type k retailer acts as if all other players are distributed between Type 0 and Type (k – 1). This structure enables us to develop a prediction of behavior for players of different types. A useful consequence of this model is that the solution is unique because each firm believes that it knows what its competitors are doing. This overcomes the common problem of multiple equilibria in simultaneous entry games (e.g., Bajari, Hong, and Ryan 2004; Seim 2006). We then fit these predictions to data to observe which distribution of types best explains observed behavior.

Our context for estimating this model is the 1997 decision by ISPs of whether to offer customers a higher-speed service (56K bps [bits per second] versus 33K bps) and, if so, which technology to provide. As Augereau, Greenstein, and Rysman (2006) discuss, firms faced a clear, reasonably well-defined technology choice game among not upgrading, upgrading to Rockwell Semiconductor Systems' K56Flex modem, upgrading to USRobotics' X2 modem, or upgrading to both. We ask the following questions: (1) How does strategic thinking affect the distribution of 56K modem technology? (2) Are the players estimated to be greater strategic thinkers more likely to survive? and (3) What factors are correlated with strategic thinking? We find that strategic thinking slowed the distribution and diffusion of the new technology; that ISPs estimated to be more likely to be strategic using 1997 data were more likely to have survived through April 2007; and that firms behaved more strategically if they competed in larger cities, if they competed in markets with more educated populations, and if they competed with more firms. Thus, although the estimate of strategic thinking is associated with increased competition, the ISPs with higher levels of strategic thinking were more likely to survive. More broadly, our results provide external validity to the current laboratory research on the CH model: In addition to the finding on survival, our estimate of the parameter that measures the distribution of strategic ability across the population is at the high end of the range found by Camerer, Ho, and Chong (2004).

The early ISP market provides an ideal setting for examining heterogeneity in strategic thinking. In addition to the clear strategic decision we described previously, many firms competed in several local markets. The dial-up nature of the technology enables us to easily define markets by local telephone calling areas. Perhaps because this was a new industry, large firms, such AOL, coexisted with very small companies run out of people's homes. Seasoned managers and MBA students competed against recent computer science graduates who had helped run the modem pools at their universities. Unlike a perfect Bayesian equilibrium approach, the CH model can account for this heterogeneity in managerial expertise in the context of simultaneous entry games, and though the decision explored in this article is not truly simultaneous, Augereau, Greenstein, and Rysman (2006) provide rich detail on why it can be reasonably viewed as a simultaneous game and, therefore, an appropriate setting for the CH model.

Overall, the CH model helps explain the variation in managerial decision making in a useful way. Our combination of behavioral game theory with the structural methods of new empirical industrial organization provides a new framework for understanding variation in the decisions of managers who face similar choices.[2] Without a model of strategic ability, it is impossible to examine how that ability affects market outcomes. Thus, such a model is a necessary step toward our finding that strategic thinking slowed the distribution and diffusion of 56K modem technology, in support of Reinganum's (1981) theoretical work on the subject. More strategic managers are *less* likely to adopt new technologies because they anticipate lower profits as a result of competition.

This suggests an important difference between the diffusion of products to consumers and to businesses: The likelihood that a given firm will adopt a business product often depends on the behavior of other competing firms. However, our results suggest that the importance of this effect is heterogeneous across managers with different abilities. For example, strategic considerations may be less important when the product is aimed at a new industry with inexperienced management than at a mature industry with lifetime professional managers.

Next, we review the two key studies on which the current research is built. Augereau, Greenstein, and Rysman (2006) provide the main data and the empirical setting, and Camerer, Ho, and Chong (2004) provide the theoretical basis for the model.

A REVIEW OF TWO KEY BUILDING BLOCKS

56K Modem Technology and Augereau, Greenstein, and Rysman (2006)

The 56K modem was introduced in 1997. These modems enabled data transfer over the Internet at a faster speed than the previous technology at a time when Internet traffic was increasing rapidly. Two modem technologies competed for

---

[2] Brown, Camerer, and Lovallo (2007) undertake a similar exercise, comparing quantal response equilibrium, cursed equilibrium, and CH in the context of movie distributors' decisions to show movies to critics. Che, Sudhir, and Seetharaman (2007) and Lim and Ho (2007) also explore the consequences of behavioral assumptions to firms. Other related studies document biases exhibited by real-world managers (Chan, Hamilton, and Makler 2007; Hortacsu and Puller 2008) and develop semiparametric models of rationalizability (Aradillas-Lopez and Tamer 2008).

the market: the X2 modem from USRobotics and the K56Flex modem from Rockwell Semiconductor Systems. These technologies had the same performance capabilities, but they differed in their ease of connection depending on local characteristics. They were also incompatible: A consumer with a given modem could only connect to an ISP at 56K speed if that ISP had the same technology.

Augereau, Greenstein, and Rysman (2006) study ISPs' choice of 56K modem technology. Specifically, ISPs that offered 33K service decided whether to offer 56K service on the X2 modem, the K56Flex modem, both, or neither. Augereau, Greenstein, and Rysman model the ISPs' problem as an entry game into two markets and assume a perfect Bayesian equilibrium. Then, they use a bivariate probit model to estimate the parameters and show that ISPs were less likely to adopt the technology that more of their competitors adopted.

Building on the work of Augereau, Greenstein, and Rysman (2006), we model an ISP's technology choice problem as an entry game of imperfect information. Then, we use CH theory to capture heterogeneity in ISP use of strategic thinking. The early ISP market is a particularly good industry to apply CH theory because (1) ISP managers are likely to be heterogeneous in experience, reasoning ability, and so forth; (2) each ISP's payoff depends on competing ISPs' technology choices; (3) the set of players and markets is well defined, unlike many other entry-type games; and (4) the decisions were largely made over a three-month period, a period short enough that a simultaneous game might be a reasonable model.

Our main data set is identical to that used by Augereau, Greenstein, and Rysman (2006). Their study provides a rich description of the data; therefore, we only briefly describe some key aspects of the data. Augereau, Greenstein, and Rysman use two ISP directories (theDirectory and Boardwatch) to collect information on ISP location (through the telephone numbers that could be used to dial in), 56K technology, and some features of the ISP. Following Augereau, Greenstein, and Rysman, we define markets by telephone switches. We consider an ISP to compete in a given switch/market if there is a local telephone call from that switch to the ISP dial-in number. We also have demographic data based mainly on the zip codes associated with each switch. The data consist of 2233 ISPs in 9070 markets for a total of 216,186 ISP–market combinations.

In Table 1, Panel A provides descriptive statistics by market, Panel B provides descriptive statistics by ISP, and Panel C provides descriptive statistics by ISP–market combination. Most variable names are self-explanatory. The variable "ISP has digital connection" is missing for several observations. We include the variable "Missing" for these observations so that we can include the digital connection variable while limiting the effect of the missing data on our results. We supplement this core data set with information collected by visiting each ISP's URL to determine which ISPs still existed in April 2007.

We observe ISPs making one of four adoption choices: (1) adopt neither technology, (2) adopt Rockwell Semiconductor Systems' K56Flex modem, (3) adopt USRobotics' X2 modem, or (4) adopt both. Augereau, Greenstein, and Rysman (2006) argue that the decision can be viewed as simultaneous because the diffusion of the technology was so rapid. Table 1, Panel B, contrasts the adoption rate for the technologies in July and October 1997. Because the bulk of the adoptions occur in this short window, the authors assume that the game can be viewed as simultaneous. We also make this assumption. To explore the consequences of this assumption, we estimated a model with the July decisions taken as given and examine changes only from July to October. The qualitative results do not change.

The descriptive statistics reveal a further complication: Most ISPs operated in multiple markets. The average ISP operated in 96 markets, and the median served 16 (equivalent to one or two local calling areas). No ISP served all switches. Multimarket ISPs operated the same technology in all their markets. This complicates our analysis because we need to alter the standard CH model to address multimarket ISPs and to constrain ISP decisions to be the same across markets. We discuss how we deal with this subsequently.

CH and Camerer, Ho, and Chong (2004)

Suppose that many players engage in a simultaneous move game in which all players' payoffs depend not only on their decision but also on other players' decisions. Therefore, players need to form expectations about what the other players will do. Although many models allow players to differ in their payoff functions, they typically assume that all players have the same ability to think through the game. Camerer, Ho, and Chong (2004) argue that this assumption is flawed. They develop CH theory, which allows players to differ in their ability to think strategically. They show that CH works well in both the entry-type game we examine here and a "p-beauty contest" game (Ho, Camerer, and Weigelt 1998; Nagel 1995).

In CH theory, players have different hierarchies of rationality. Type 0 players do not consider their competitors, Type 1 players assume that all competitors are Type 0, Type 2 players assume that the other players are a combination of Type 0 players and Type 1 players, and Type k players assume that the other players are distributed between Type 0 and Type (k – 1). Camerer, Ho, and Chong (2004) provide evidence that a Poisson distribution effectively describes the observed distribution of players. We rely on this evidence to support our model and identification. In the CH model, a Type k player assumes that all other players are distributed truncated Poisson between Type 0 and Type (k – 1). The model assumes that the distribution of types in the population has the same Poisson parameter as the truncated Poisson used by players to assess competitor types.

We interpret this hierarchy of rationality as heterogeneity in strategic sophistication. This interpretation relies on prior experimental literature that shows that players who appear to think strategically show decision processes consistent with this idea (Bosch-Domenech et al. 2002; Camerer and Johnson 2004; Chong, Camerer, and Ho 2005; Costa-Gomes, Crawford, and Broseta 2001). Therefore, Type 0 managers do not consider competitors. Instead, they consider the characteristics only of their firm and their market. Given their own characteristics, Type 1 players best respond to a situation in which all their competitors are Type 0, and so on. A key difference between CH and Nash is that in CH models, some players will be surprised by the behavior of their competitors because they did not correctly conjecture their competitors' choices.

Table 1

SUMMARY STATISTICS

A: By Market (N = 9070)

Variable	*M*	*SD*	*Minimum*	*Maximum*
Number of ISPs in the market	23.84	29.80	1	139
Number of backbone providers	6.579	17.40	0	106
% population urban	.4612	.3993	0	1
% population in different county five years ago	.1704	.0807	0	.8667
Median household income (in U.S. dollars)	42,644	14,719	6,136	200,001
% population college graduate	.0848	.0515	0	.825
Number of business establishments per person	.0235	.0067	.0028	.0981

B: By ISP (N = 2233)

Variable	*M*	*SD*	*Minimum*	*Maximum*
Chose Rockwell Semiconductor Systems (A) in October	.2342	.4236	0	1
Chose USRobotics (B) in October	.1742	.3794	0	1
Chose both in October	.0828	.2757	0	1
Chose neither in October	.5087	.5000	0	1
Chose Rockwell Semiconductor Systems (A) in July	.0502	.2183	0	1
Chose USRobotics (B) in July	.0828	.2757	0	1
Chose both in July	.0121	.1093	0	1
Chose neither in July	.8549	.3523	0	1
Number of markets served	96.81	451.9	1	4916
ISP has digital connection (T1 or ISDN)	.7443	.4364	0	1

C: By ISP–Market (N = 216,186)

Variable	*M*	*SD*	*Minimum*	*Maximum*
Chose Rockwell Semiconductor Systems (A) in October	.1347	.3414	0	1
Chose USRobotics (B) in October	.1706	.3762	0	1
Chose both in October	.0905	.2869	0	1
Chose neither in October	.6042	.4890	0	1
Chose Rockwell Semiconductor Systems (A) in July	.0149	.1212	0	1
Chose USRobotics (B) in July	.0449	.2071	0	1
Chose both in July	.0083	.0906	0	1
Chose neither in July	.9319	.2519	0	1
Number of ISPs in the market	61.08	35.83	1	139
Number of backbone providers	22.17	33.19	0	106
ISP has digital connection (T1 or ISDN)	.5981	.4903	0	1
Missing	.2873	.4525	0	1
% population urban	.6808	.3793	0	1
% population in different county five years ago	.1663	.0850	0	.8667
Median household income (in U.S. dollars)	50,353	18,249	6,136	200,001
% population college graduate	.1068	.0574	0	.825
Number of business establishments per person	.0241	.0061	.0028	.0981

MODEL AND EMPIRICAL STRATEGY

In this section, we build on Camerer, Ho, and Chong's (2004) work and apply the CH model to the ISP data. Our specification differs from the definitions used in laboratory experiments. In particular, to apply the model to data outside the laboratory, we use observable data to allow ISPs to be heterogeneous in ways other than strategic thinking. Augereau, Greenstein, and Rysman (2006) show that ISP- and market-specific characteristics influence the decision of whether to adopt 56K modem technology at all and, if so, which technology to adopt. Therefore, we add the ISP- and market-level covariates used in that research. This means that rather than choosing randomly, a Type 0 player's choice is the one with the higher intrinsic value to that player, independent of competitor choices. Higher-level players also consider the intrinsic value of each choice in addition to competitor behavior. In what follows, we formalize this approach.

Suppose that there are J ISPs (j = 1, ..., J) that operate in markets indexed by i. These ISPs observe market-specific characteristics x_i and ISP-specific characteristics x_j. In addition, each ISP has four choices: adopt neither technology, adopt Rockwell Seminconductor Systems' K56Flex modem (technology "A"), adopt USRobotics' X2 modem (technology "B"), or adopt both. We denote this choice set as $s_j = \{0, A, B, AB\}$ and normalize $E[\pi_{ij}^{0}|k] = 0$.

In our model, $E[\pi_{ij}^{s}|k]$ depends on the ISP's level of strategic thinking, in addition to market-level and ISP characteristics. As we discussed previously, we assume that a Type 0 ISP (denoted by j) does not take competitor actions into account. Therefore, its expected profit in market i is only a function of ISP- and market-level characteristics.

$$(1)\qquad E[\pi_{ij}^{A}|0] = \beta_0^A + x_i\beta_1^A + x_j\beta_2^A,$$

$$E[\pi_{ij}^{B}|0] = \beta_0^B + x_i\beta_1^B + x_j\beta_2^B.$$

Here, x_i are market-level characteristics that affect the profitability of adoption, and x_j are ISP characteristics. For a Type $k > 0$ ISP, its expected profit in market i is

$$(2)\qquad E[\pi_{ij}^{A}|k] = \beta_0^A + x_i\beta_1^A + x_j\beta_2^A + E[\psi_1^A(n_i^A + 1) + \psi_2^A n_i^B + \psi_3^A n_i^{AB}|X, \theta, k],$$

$$E[\pi_{ij}^{B}|k] = \beta_0^B + x_i\beta_1^B + x_j\beta_2^B + E[\psi_1^B n_i^A + \psi_2^B(n_i^B + 1) + \psi_3^B n_i^{AB}|X, \theta, k].$$

Here, n_i^A, n_i^B, and n_i^{AB} are the (expected) number of market i competitors that adopt technologies A, B, and both, respectively. Therefore, these will be a function of the market and competitor characteristics. Then, ψ represents coefficients on expected competitor behavior, and β represents coefficients on other parameters of the profit function. For Type 1 ISPs, we calculate the values for n_i^A, n_i^B, and n_i^{AB} assuming that all their competitors are Type 0 ISPs that choose the technology that maximizes their profits. For Type 2 ISPs, we calculate these values assuming that all their competitors are either Type 0 or Type 1. For Type k ISPs, we calculate these values assuming that all their competitors are distributed between Type 0 and Type $(k - 1)$. In this way, we assume that all ISP- and market-specific characteristics are public information. Thus, any ISP can observe the characteristics of all the other ISPs and predict their behavior according to the distribution of types. Given ISP and market characteristics and the parameters of the model, the choices of Type 0 ISPs are perfectly predictable up to the idiosyncratic error in the profit function. Consequently, the choices of higher-level ISPs are also iteratively known given the distribution of types. Our modeling approach to study this type-dependent choice problem is similar to approaches that examine state-dependent choice problems (e.g., Netzer, Lattin, and Srinivasan 2008). Here, we have type distributions and type-dependent choice probabilities, while those methods have similar state distributions and state-dependent choice probabilities.

Following Camerer, Ho, and Chong (2004), we assume that this distribution is a truncated Poisson. In particular, we assume that types are distributed Poisson with parameter τ. The Poisson distribution is convenient because a single parameter describes it. As τ increases, the distribution of player types becomes relatively more strategic. We can assume that a Type k ISP believes that its competitors are distributed truncated Poisson (at $k - 1$) with the same parameter τ. Alternatively, to estimate how strategic ability varies with market and ISP characteristics, we modify this distribution to allow the Poisson parameter to vary with these characteristics. In particular, we set $\ln(\tau^j) = \gamma_0 + \gamma_1 z_{ij}$, where z includes three market-level characteristics (the number of competitors in the market, the percentage of the population that lives in an urban area, and the percentage of the population that has graduated college) and a firm-level characteristic (number of markets served).[3]

Given its type, ISP j picks the choice that maximizes its profit: $\text{Max}_{s_j}\{0, \pi_j^A, \pi_j^B, \pi_j^{AB}\}$. Because ISPs operate in many markets and offer the same technology in all markets, we assume that they add up the profits across markets and choose the technology that gives the highest total profit. Then,

$$(3)\qquad \pi_j^0 = 0,$$

$$\pi_j^A = \sum_i E[\pi_{ij}^A|k] + v_j^A,$$

$$\pi_j^B = \sum_i E[\pi_{ij}^B|k] + v_j^B,$$

$$\pi_j^{AB} = \sum_i E[\pi_{ij}^A|k] + \sum_i E[\pi_{ij}^B|k] + v_j^A + v_j^B + \Gamma$$

$$\begin{pmatrix} v_j^A \\ v_j^B \end{pmatrix} \sim N(0, \Sigma) \text{ and } \Sigma = \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix},$$

where Γ represents the additional payoff of adopting both technologies beyond the sum of adopting each technology. Because ρ and Γ are not separately identified in a setting such as ours (Gentzkow 2007), we normalize Γ to be 0. The error terms v_j are ISP-level shocks that affect the profitability of the different technologies observed by the ISPs but not by the econometrician.

We can now predict multimarket ISP j's choice probabilities, conditional on its type. The general procedure is as follows: We first calculate every ISP's branch-level profits (or market-level profits). Then, we add them up by ISP to get the ISP-level profits. Next, we consider each ISP's aggregate profit maximization problem to determine its technology adoption decision. Then, we map every ISP's decision to all its branches. We repeat this procedure to get every ISP's expectation about other ISPs' decisions, conditional on it being of each possible type. We calculate the ISP's choice probabilities assuming that the ISP is maximizing profits, conditional on it being of each type.

Formally, the first step is to calculate ISP j's choice probabilities if it is of Type 0 (with probability $p_k^0[j]$, where k is the highest type possible): $p_k^0(j) \rightarrow Pr_j^0 \leftrightarrow s_j^0 \in \{0, A, B, AB\}$. Similarly, we calculate all the other ISPs' choice probabilities if they are Type 0. Then, we map s_j^0 onto s_{ij}^0, Pr_j^0 onto $Pr_{i,j}^0$, $i = j_1, ..., j_B$, $j = 1, 2, \ldots, J$ (where $J = 2233$ in our data). Second, if ISP j is a Type 1 ISP (with probability $p_k^1[j]$), based on its beliefs about other ISPs' types and branch-level decisions ($Pr_{i,j}^0$), we calculate j's expected branch-level profits. Adding up these profits, we obtain j's aggregate profit level and its choice probabilities from its profit-maximizing problem: $p_k^1(j) \rightarrow Pr_j^1 \leftrightarrow s_j^1 \in \{0, A, B, AB\}$. We similarly calculate all the other ISPs' choice probabilities if they are Type 1 ISPs, and then we map s_j^1 onto s_{ij}^1, Pr_j^1 onto $Pr_{i,j}^1$, $i = j_1, ..., j_B$, $j = 1, 2, \ldots, J$. We repeat this procedure until we get all ISPs' choice probabilities under all types.

Mathematically, a Type k ISP j's expected number of competitors adopting the technologies in market i can be shown by the following vector:

---

[3] Although it may seem unintuitive to include market-level characteristics, we believe that it is an empirical question whether they matter (and we find that they do). We include the firm-level covariate "number of markets served" because we believe that it makes intuitive sense, even though it is not significant in many specifications.

$$(4)\qquad \{E_j(n_i^A|k),\ E_j(n_i^B|k),\ E_j(n_i^{AB}|k)\} = \left\{ \sum_{m=0}^{m=k-1} \sum_{l \neq j} [p_{k-1}^m(l) \times Pr_{i,l}^m(A)],\ \sum_{m=0}^{m=k-1} \sum_{l \neq j} [p_{k-1}^m(l) \times Pr_{i,l}^m(B)],\ \sum_{m=0}^{m=k-1} \sum_{l \neq j} [p_{k-1}^m(l) \times Pr_{i,l}^m(AB)] \right\}.$$

Here, all Type k ISPs assume that any other ISP (denoted by j) is distributed according to a normalized Poisson distribution with one parameter τ^j, from Type 0 $[p_{k-1}^0(j)]$ to Type (k – 1) $[p_{k-1}^{k-1}(j)]$. Again, note that each ISP has an idiosyncratic Poisson distribution parameter τ^j, whereas in the original CH model, each group of lab participants has one idiosyncratic Poisson distribution parameter τ. In other words, in the original CH research, all participants' types are drawn from the same Poisson distribution with one parameter τ, whereas here, we draw each multimarket ISP from a generalization of the Poisson distribution in which the τ varies with the ISP's characteristics according to the coefficients on these characteristics.

Next, we can compute ISP j's aggregate choice probabilities (weighted by $p_k^m[j]$) with respect to the choice set {0, A, B, AB}:

$$(5)\quad p_j(0) = \sum_{l=0,\dots,k} p_k^l(j) \times Pr_j^l(0),\ I_j(0) = \begin{cases} 1 \text{ if } s_j = 0 \\ 0 \text{ if otherwise} \end{cases},$$

$$p_j(A) = \sum_{l=0,\dots,k} p_k^l(j) \times Pr_j^l(A),\ I_j(A) = \begin{cases} 1 \text{ if } s_j = A \\ 0 \text{ if otherwise} \end{cases},$$

$$p_j(B) = \sum_{l=0,\dots,k} p_k^l(j) \times Pr_j^l(B),\ I_j(B) = \begin{cases} 1 \text{ if } s_j = B \\ 0 \text{ if otherwise} \end{cases},$$

$$p_j(AB) = \sum_{l=0,\dots,k} p_k^l(j) \times Pr_j^l(AB),\ I_j(AB) = \begin{cases} 1 \text{ if } s_j = AB \\ 0 \text{ if otherwise} \end{cases}.$$

This gives the following likelihood function:

$$(6)\quad \prod_j \{[p_j(0)]^{I_j(0)}[p_j(A)]^{I_j(A)}[p_j(B)]^{I_j(B)}[p_j(AB)]^{I_j(AB)}\}.$$

We estimate this likelihood function using a genetic "differential evolution" algorithm (Storn and Price 1997). This method is simple and efficient for global optimization over continuous spaces. We combine this with a GHK simulator using 50 draws to simulate the choice probabilities (we choose this number from Monte Carlo evidence in Keane [1994] and elsewhere).[4]

Our model is identified because it predicts that different types will behave differently in otherwise identical situations. It relies on the assumption that we can assess the attractiveness of adopting the technologies to each ISP. For example, suppose that we observe a market with three ISPs and that we know that the optimal number of adopters is two. If we observe three adopt, we can assume that they are all Type 0. If we observe none adopt, they must all be Type 1 (and expect that their competitors both adopted as Type 0s). The model generates such decision rules, and we compare these predictions with the data. Each τ generates a distribution of types. For example, if $\tau = 1$, 37% of players will be Type 1, and fewer than 1% will be Type 5. In contrast, if $\tau = 3$, 16% of players will be Type 1, and 11% of players will be Type 5. Given that we have a large number of ISPs (2233) serving an even larger number of markets (9070), we can find the value for τ that best fits the data to distribution of types predicted by the model.

RESULTS

Model Estimates

In this section, we discuss the parameter estimates. Table 2 presents the main results. Table 2, Column 1, uses four different characteristics of the ISPs and the markets they serve to define τ. The results suggest that firms that operated in areas with more educated populations, that faced more competitors, and that operated in urban areas had higher values of τ. (The negative coefficient for the number of markets is not robust to alternative specifications, and therefore we do not emphasize it.) For example, this means that the strategic thinking distributions for firms that faced more competitors first-order stochastically dominate the distributions for other types of firms. Therefore, firms with these characteristics are more likely to be higher-type players and thus behave more strategically. These results are consistent with prior laboratory research. For example, Ho, Camerer, and Weigelt (1998) find that strategic thinking increases as the number of competitors increases, and Chong, Camerer, and Ho (2005) find that laboratory participants who attended a high-quality school are more strategic.

Column 2 estimates the model in which we assume τ to be equal across all ISPs. The estimated τ is 2.67 (i.e., $e^{.9809}$). This value means that the numbers of Type 0, Type 1, Type 2, Type 3, Type 4, and Type 5 and above are 164, 437, 583, 519, 346, and 185, respectively. This is at the high end of the range of values for τ found in Camerer, Ho, and Chong (2004). For example, the median value from all the experiments they examine is 1.6, and the maximum value is 4.9. For a group of portfolio managers, τ is 2.8. We view this as providing external validity for the CH model: Given that this is a business decision, we expect managers to think it through more carefully than undergraduate students in a lab. Still, the level of strategic thinking is well within the range of the lab, suggesting that the laboratory insights indeed apply in our setting.

Rows 6, 7, 9, and 10 in Table 2 show that ISPs typically differentiate from their rivals. The parameter ψ is negative when estimating a firm's incentives to adopt the same modem technology as its competitors and positive when estimating incentives to adopt a different technology. For example, Rows 6 and 7 show that if an ISP adopted the K56Flex modem, all else being equal, its competitor was

---

[4] In the main results, we treat all ISPs' technology adoption decisions as simultaneous regardless of whether they first occur in July or October 1997. As Augereau, Greenstein, and Rysman (2006) discuss, the descriptive statistics suggest that this is a reasonable thing to do. For example, in Table 1, Panel B, more than four times as many ISPs had adopted Rockwell Semiconductor Systems' technology in October than in July.

Table 2
MAIN RESULTS

			1		*2*	
			Coefficient	*SE*	*Coefficient*	*SE*
Correlates with strategic thinking parameter τ (γ)	1	Constant (γ_0)	.6716***	.0364	.9809***	.0152
	2	ln(number of markets served)	–.0221***	.0059		
	3	ln(number of ISPs in market)	.0403***	.0137		
	4	% population urban	.1569***	.0481		
	5	% population college graduate	1.1731***	.2177		
Competitive incentives for adopting Rockwell Semiconductor Systems' K56Flex (ψ^A)	6	Number of ISP's on Rockwell Semiconductor Systems	–2.8343***	.4297	–3.1408***	.4098
	7	Number of ISP's on USRobotics	1.0453***	.1929	2.1284***	.3243
	8	Number of ISP's on both technologies	–2.3236***	.4742	–5.3661***	.8573
Competitive incentives for adopting USRobotics' X2 (ψ^B)	9	Number of ISP's on Rockwell Semiconductor Systems	.2653***	.0927	.3086***	.0422
	10	Number of ISP's on USRobotics	–1.0847***	.1809	–.8824***	.0699
	11	Number of ISP's on both technologies	1.7539***	.2800	1.2991***	.1593
Controls: nonstrategic factors that affect adopting Rockwell Semiconductor Systems' K56Flex (β^A)	12	Constant	–1.8913**	.7786	–2.3810***	.0773
	13	ln(number of ISPs in market)	.3648***	.0737	–.1112***	.0205
	14	ISP has digital connection	2.3463***	.3541	2.5445***	.3696
	15	Missing	–.6874***	.1592	–.0368***	.0100
	16	ln(median household income)	.2110***	.0801	.2575***	.0070
	17	Number of business establishments per person	3.2702**	1.6001	3.0050**	1.2269
	18	% population college graduate	–2.1197**	.8621	–3.3205***	.3541
	19	% population urban	.2318	.1916	.2919***	.0830
	20	% population in different county five years ago	–.0557	.5879	1.1854***	.2251
	21	Number of backbone providers	–.0428***	.0064	–.0017**	.0008
Controls: nonstrategic factors that affect adopting USRobotics' X2 (β^B)	22	Constant	–6.3662***	.5978	–3.2724***	.0186
	23	ln(number of ISPs in market)	.0042	.0154	.0661***	.0068
	24	ISP has digital connection	1.0491***	.1892	.9094***	.0754
	25	Missing	.0207	.0272	–.0002	.0010
	26	ln(median household income)	.5909***	.0567	.2964***	.0028
	27	Number of business establishments per person	–4.2215*	2.4711	–.9406	.5672
	28	% population college graduate	2.2869***	.6438	1.3414***	.3461
	29	% population urban	–.4507***	.1212	–.1257***	.0274
	30	% population in different county five years ago	.1165	.3937	–.1849	.1407
	31	Number of backbone providers	.0276***	.0078	–.0111***	.0009
	32	ρ	–.1765	.2710	.0617	.2527
	33	Log-likelihood	–2623.0		–2644.8	

*Significant at the 90% confidence level.
**Significant at the 95% confidence level.
***Significant at the 99% confidence level.

more likely either to have adopted the X2 modem or not to have adopted at all. Furthermore, we find that the incentives not to adopt the same technology as a competitor were larger than the incentives to adopt the competing technology. This implies that strategic thinking may have led to an overall decrease in adoption of 56K modems. We examine this idea in greater detail subsequently.

We explore robustness to several alternative specifications in the Web Appendix (see http://www.marketingpower.com/jmroct09). In general, these results confirm our main findings.

Comparison with Augureau, Greenstein, and Rysman (2006)

Our results are consistent with Augereau, Greenstein, and Rysman (2006), though a comparison provides important additional insights into the consequences of allowing heterogeneity in strategic ability. Their objective was to determine whether ISPs coordinate to take advantage of potential network externalities or differentiate to generate local market power. As in our estimation, they allow for both coordination and differentiation to arise in their analysis. The key difference between our research and theirs is that we allow for heterogeneity in managerial ability. Their primary contribution and main result is that ISPs tended to differentiate from their rivals when choosing which 56K modem technology to adopt. This is consistent with our results for ψ in Rows 6, 7, 9, and 10 in Table 2. Our primary empirical contribution instead arises from the estimates of the strategic ability parameter τ and the simulations of the consequences of varying strategic ability. Thus, our model provides additional and distinct insights because we can assess how ability affects outcomes.

A direct comparison of our results with those of Augereau, Greenstein, and Rysman provides an additional insight: Our estimated level of differentiation is much stronger (in significance and relative coefficient magnitude) than the one they estimate. Given the assumptions of the CH model, this is expected: Low-type ISPs may not differentiate effectively. These would be averaged with the others had we estimated a perfect Bayesian equilibrium model. In the CH model we estimate, the coefficients are driven only by the firms that behave strategically.

It is important to note that, in general, the CH model does not fit the data better than the perfect Bayesian equilibrium model used in Augereau, Greenstein, and Rysman (2006). We estimated each of the specifications they presented, and our estimated log-likelihoods are similar to theirs with one notable exception: Our model fits the data better than theirs when we treat the July 1997 decisions as exogenous (i.e., when making decisions in October, ISPs observe their competitors' decisions in July). We believe that our model fits the data better in this case because these decisions are more likely to be truly simultaneous because of the short time horizon. In particular, suppose that early adoption decisions (e.g., those in April) are observable by later adopters (e.g., those in October). Then, the ISPs making a decision in October will be able to best respond to the early adopters. This means that the resulting adoption patterns will more closely resemble Nash. In contrast, because it takes time to set up the technology, it is unlikely that late adopters (those in October) will be able to best respond to ISPs that adopted in August. Therefore, it is more likely that conjectures about competitor behavior over a short time horizon will rely on k-step thinking. In this way, treating the July decisions as exogenous and observed, and then modeling only the subsequent decisions as simultaneous, is closer to the simultaneous game that we model. Therefore, this is suggestive of the usefulness of the CH model over the Nash model when the game is truly simultaneous.

Did High τ Firms Do Better?

In this subsection, we provide a test of the external validity of our estimates. We cannot explicitly test our model against the Nash equilibrium. Instead, we examine whether the ISPs that survived until April 2007 had a higher estimated value of τ. If the firms that are estimated to be more strategic are more likely to survive, we believe that this provides some surface validity for our strategic ability parameter.[5]

Our data contain the URLs of 2233 ISPs that were operating in 1997. We manually visited each of these 2233 URLs again in April 2007. Of the 2233 URLs, 1107 were still operating as ISPs that provided dial-up Internet, DSL, or both. Another 933 were no longer operating as ISPs. The remaining 193 were operating as ISPs, but the visitor was forwarded to another Web site.[6]

We use the information in Table 3 to assess the correlation between the strategic ability parameter (τ) predicted from our model and survival through 2007. All three columns show the same substantive result: ISPs that survived (through continued operations or acquisition) have a higher value of τ. We use Table 2, Column 1, to predict τ. Column 1 defines survival as either still operating as an ISP or having been acquired. Column 2 takes the ISPs that were acquired out of the data. Column 3 treats acquired ISPs as having exited.

Overall, Table 3 shows that higher τ firms did better in that they were more likely to have survived for ten years. We do not mean to suggest that the 56K modem decision itself led to survival. Instead, we argue that high strategic ability overall is likely correlated with observed strategic behavior in the decision to adopt 56K modems. Firms that survived had higher estimated levels of strategic thinking in this context, and therefore we argue that they likely had higher levels of strategic thinking overall. Still, this correlation between survival and strategic ability needs to be treated as suggestive rather than conclusive evidence in favor of our model. It is possible that variables correlated with estimated strategic thinking, τ, are correlated with survival for reasons independent of strategic thinking. Although this is unlikely to be the case for the number of competitors—all else being equal, more competitors should lead to more failures—it is possible that ISPs that operated in more urban and educated areas had high survival rates. Subsequently, we describe several limitations of the model in greater detail.

Table 3

ISPS WITH HIGHER τ ARE MORE LIKELY TO HAVE SURVIVED TO APRIL 2007

	1	*2*	*3*
	All ISPs (τ Defined as in Table 2, Column 3)	*Only ISPs That Maintain an Independent Web Site*	*Acquired ISPs Treated as Having Exited*
τ	.2259**	.2247**	.1943**
	(.0915)	(.0941)	(.0907)
Constant	–.3848	–.4819*	–.5203**
	(.2413)	(.2481)	(.2394)
Log-likelihood	–1514.4	–1403.7	–1545.4
N	2233	2040	2233

*Significant at the 90% confidence level.

**Significant at the 95% confidence level.

Notes: Probit regression of survival on predicted τ. Standard errors are in parentheses.

Underlying this test is the assumption that strategic thinkers are more likely to be profitable and thus more likely to survive. While Stahl (1993) shows in an evolutionary setting that some nonstrategic thinkers survive if they are lucky enough to randomly choose a good strategy, we find that strategic thinkers (i.e., those with higher estimated τ) earn a higher profit on average in our model. In particular, Table 4 shows that predicted profits and the predicted strategic ability parameter τ are strongly and positively correlated within the model. The purpose of this table is simply to show that in our model, in general, ISPs with higher τ earn higher profits: Strategic thinkers are more likely to

Table 4

THE MODEL PREDICTS THAT ISPS WITH HIGHER τ WILL HAVE HIGHER PROFITS

	1	*2*
	All ISPs (τ Defined as in Table 2, Column 3)	*Only ISPs That Maintain an Independent Web Site*
τ	.4671*	.4605*
	(.0919)	(.0939)
Constant	–.8348*	–.8283*
	(.2425)	(.2479)
R-square	.0115	.0117
N	2233	2040

*Significant at the 99% confidence level.

Notes: Ordinary least squares regression of predicted profits on predicted τ. Standard errors are in parentheses.

---

[5] Haile, Hortacsu, and Kosenok (2008) suggest this type of validation strategy in their work on the difficulties in estimating quantal response equilibria using data from outside the laboratory.

[6] For example, typing "www.abts.net" forwards the visitor to "www.earthlink.net." We interpret this as the ISP having been acquired but show robustness to not including these ISPs.

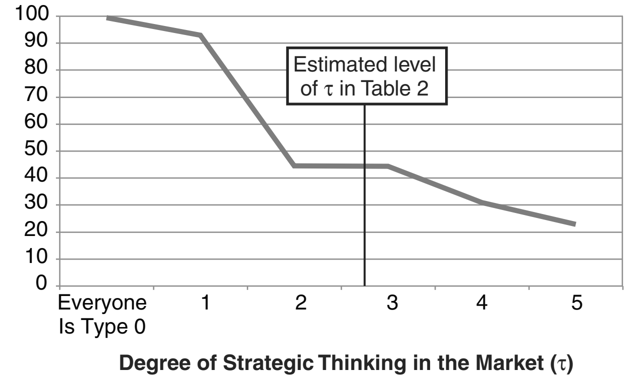
be profitable. Therefore, the result that strategic thinkers survive beyond the estimation period provides external validity for our assertion that τ measures strategic thinking.

Consequences of Strategic Thinking on 56K Modem Diffusion

Next, we examine how different levels of strategic thinking may lead to different outcomes. Based on the coefficients of Table 2, Column 1, Figures 1 and 2 show simulation results in which we allow the distribution of strategic thinking to vary. Figure 1 shows that the percentage of ISPs that provide at least one 56K modem technology falls as strategic thinking rises. If every firm is a Type 0 player, provision of one or the other technology is greater than 99%. However, provision falls under 50% as τ approaches 2, and it falls under 25% as τ approaches 5. Beyond τ = 5, the effect of increasing τ appears to have little systematic impact on behavior. Thus, Figure 1 suggests that strategic thinking slows the overall diffusion of the technology: If the ISPs are more strategic, fewer will offer the upgraded service to their customers. Figure 2 adds two further insights: (1) Fewer ISPs will adopt both technologies as strategic thinking rises, and (2) the relative shares of the competitors will level off as strategic thinking rises. These results reflect the incentive to differentiate. When firms consider the competition, the model suggests that they understand that providing a different service from the competition increases profitability.

Figure 1

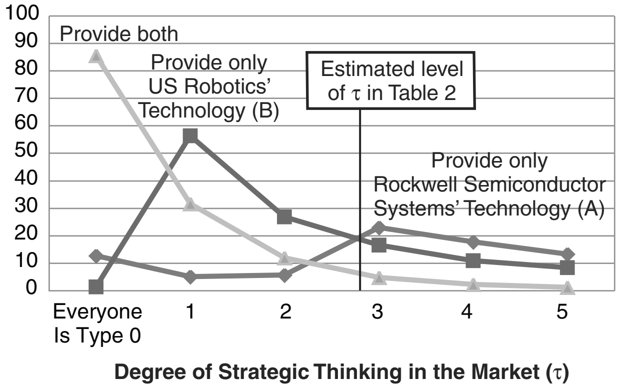
% ISPS THAT PROVIDE AT LEAST ONE 56K MODEM TECHNOLOGY



Notes: Simulations are based on Table 2, Column 2.

Figure 2

% ISPS THAT PROVIDE EACH 56K MODEM TECHNOLOGY



Notes: Simulations are based on Table 2, Column 2.

In addition to these results, we conducted a simulation in which all players are Type 1. Under this situation, fewer than 1% adopt both technologies, and more than 95% adopt USRobotics' technology, apparently in an attempt to differentiate from their expected Type 0 competition. This simulation shows the importance of heterogeneity in strategic ability in providing interesting and reasonable insights. It is not simply bounded rationality: If everyone is boundedly rational in the same way but no structure is imposed in terms of reasonable beliefs, the market outcomes become unbalanced.

In summary, the simulation results suggest that allowing for heterogeneity in strategic ability helps us understand variation in ISP technology choices. Competitive considerations slowed the diffusion of 56K modem technology; however, diffusion would have been even slower if the ISPs were more strategic (as might be expected as the industry matures).

LIMITATIONS

As in any empirical work, this research has several limitations. First, we assume, rather than test, the CH model. Although we provide some evidence of external validity, our model does not nest Nash equilibrium assumptions. Our goal has been to understand the drivers of changes in the ability distribution parameter τ, assuming that the model behind it is correct. We rely on the prior experimental literature to support our modeling assumptions. Drawing on this literature, we measure strategic ability as the number of thinking steps a firm goes through to differentiate from its rivals. Therefore, two firms with different characteristics behave differently in the model in a probabilistic sense.

It is possible that the observed variation in managerial ability is simply a variation in unobserved heterogeneity along other dimensions. Our estimate of heterogeneity in the ability to correctly conjecture competitor behavior puts a specific structure on unobserved heterogeneity. Given the cross-sectional nature of our data and that ISPs choose the same technologies in every market, we cannot allow for unobserved heterogeneity in the likelihood of ISPs upgrading their services or in the attractiveness of upgrading across markets. These limitations can be overcome in future work with alternative settings in which firms make different decisions in different markets. In this case, firm and market (random or fixed) effects can be identified.

In addition, although we find that ISPs with high estimated τ were more likely to survive (despite being less likely to adopt 56K modems and facing more competitors) and that the results on what drives the strategic ability parameter are intuitive, without a clear instrument that is correlated with τ but not with survival, this evidence remains suggestive because it is largely identified off the functional form. Furthermore, ISPs with more competitors that operate in educated urban markets are more likely to be strategic. Still, we can put forth alternative explanations for our intuitive results and the correlation between having a high estimated τ and surviving. Thus, we cannot maintain that the CH model is somehow "better" than assuming Nash behavior. Indeed, our model does not consistently fit the data better than Augereau, Greenstein, and Rysman's (2006) Nash equilibrium model. Instead, we argue that the assumptions of the CH model enable us to learn different things from the data than a Nash model.

Second, a somewhat restrictive assumption inherent in the CH theory is that all players think they are smarter than all other players. In other words, the CH theory precludes the possibility that players expect their competitors to be their equals in level of strategic thinking. However, if we allow players to think that rivals may have equal ability, this will result in a mutually best response through infinitely many iterations, meaning that the uniqueness of the solution would be lost.

Third, we do not have rich data on managerial characteristics. Although we found that several market-level characteristics were related to our measure of strategic ability, we cannot report much about the manager-specific factors that are related to ability. More information on managers would allow for a deeper understanding of the types of managers that are more strategic.

Fourth, we identify a specific kind of ability: the ability to correctly conjecture competitor behavior. We cannot offer anything about the ability of managers in other dimensions that are relevant to success.

Finally, the empirical setting might differ from the model and affect the results in unforeseen ways. For example, multimarket ISPs may weight markets differently than our assumptions suggest. They may be forward-looking firms that consider future market changes that we cannot measure. There may be unobservable shocks to adoption costs or benefits that affect technology choice. For example, a temporary, locally focused price promotion for one technology may influence our results on strategic behavior. Furthermore, although adoption takes place over a short period, the game we study is not truly a simultaneous game. The ISPs may respond to each other's decisions quickly. Finally, some ISPs may also be playing a coordination game rather than a differentiation game. Although Augereau, Greenstein, and Rysman (2006) find that ISPs did not behave this way on average, if some ISPs were coordinating, they would appear in the estimates to be less strategic.

CONCLUSION

As the first study to our knowledge to combine behavioral game theory with the structural models of new empirical industrial organization, this research provides a new framework for understanding variation in the decisions of managers who face similar choices. This framework enables us to show how strategic thinking affects outcomes.

We find that strategic thinking slowed the diffusion of 56K modem technology, in support of Reinganum's (1981) theoretical work on the subject. In particular, our results suggest that strategic thinking by some customers substantially reduced modem distribution for both Rockwell Semiconductor Systems and USRobotics. This impact suggests that competitive considerations in technology adoption are important to managers of business-to-business products and for policy makers trying to encourage technology diffusion. That said, the degree to which competitive considerations matter depends on the strategic sophistication of the firms: Our simulations suggest that adoption rates would have been lower if the average level of strategic sophistication were higher. In general, in industries with inexperienced managers, competitive considerations may be less important. Therefore, this research builds on the rich existing literature that focuses on the diffusion of new consumer-oriented products (starting with Bass 1969).

Our results suggest two new variables that should be considered when a new product is aimed at businesses: (1) the strategic consequences of the product for the targeted industry and (2) the strategic ability of the players. The competitive considerations of business customers affect diffusion, and this is particularly important in industries with sophisticated, experienced managers. Consistent with Soberman's (2007) theoretical results, this means that it may be most effective for business-to-business marketers to target just one firm in each market because the marginal returns to targeting multiple competing customers will be lower. Our results also indicate that incentives for business customers to differentiate from competitors may hinder the creation of winner-take-all markets.

We show that estimating heterogeneity in managerial types is feasible and provides some notable insights. Several opportunities remain for future work that builds structural econometric models from the assumptions of behavioral games. We encourage researchers to examine whether strategic thinking limits (or encourages) technology adoption in other industries and whether this impact increases as industries mature and managers become more experienced. Similarly, scholars could apply this modeling technique to other settings to explore further how strategic thinking affects market outcomes.

REFERENCES

Aradillas-Lopez, Andres and Elie Tamer (2008), "The Identification Power of Equilibrium in Games," *Journal of Business and Economic Statistics*, 26 (3), 261–83.

Ataman, Berk M., Carl Mela, and Harald J. van Heerde (2008), "Building Brands," *Marketing Science*, 27 (6), 1036–1054.

Augereau, Angelique, Shane Greenstein, and Marc Rysman (2006), "Coordination vs. Differentiation in a Standards War: 56K Modems," *RAND Journal of Economics*, 37 (4), 887–909.

Bajari, Patrick, Han Hong, and Stephen Ryan (2004), "Identification and Estimation of Discrete Games of Complete Information," National Bureau of Economic Research Working Paper No. T0301.

Bass, Frank M. (1969), "A New Product Growth for Model Consumer Durables," *Management Science*, 15 (5), 215–27.

Bosch-Domenech, Antoni, Jose G. Montalvo, Rosemarie Nagel, and Albert Satorra (2002), "One, Two, (Three), Infinity,...: Newspaper and Lab Beauty-Contest Experiments," *American Economic Review*, 92 (5), 1687–1701.

Brown, Alexander L., Colin F. Camerer, and Dan Lovallo (2007), "Limited Strategic Thinking in the Field: The Box Office Premium to Unreviewed 'Cold Opened' Movies," working paper, Division of Humanities and Social Sciences, California Institute of Technology.

Camerer, Colin (2003), *Behavioral Game Theory: Experiments in Strategic Interaction*. Princeton, NJ: Princeton University Press.

———, Teck-Hua Ho, and Juin-Kuan Chong (2004), “A Cognitive Hierarchy Model of Games,” *Quarterly Journal of Economics*, 119 (3), 861–98.

——— and Eric J. Johnson (2004), “Thinking About Attention in Games: Backward and Forward Induction,” in *The Psychology of Economic Decisions*, Isabelle Brocas and Juan Carillo, eds. New York: Oxford University Press, 111–30.

Chan, Tat Y., Barton H. Hamilton, and Christopher Makler (2007), “Using Expectations Data to Infer Managerial Objectives and Choices,” working paper, Olin Business School, Washington University.

Che, Hai, K. Sudhir, and P.B. Seetharaman (2007), “Bounded Rationality in Pricing Under State-Dependent Demand: Do Firms Look Ahead? How Far Ahead?” *Journal of Marketing Research*, 44 (August), 434–49.

Chong, Juin-Kuan, Colin F. Camerer, and Teck-Hua Ho (2005), “Cognitive Hierarchy: A Limited Thinking Theory in Games,” in *Experimental Business Research*, Vol. 3, Rami Zwick and Amnon Rapoport, eds. New York: Kluwer Academic Publishers, 203–228.

Costa-Gomes, Miguel and Vincent P. Crawford (2006), “Cognition and Behavior in Two-Person Guessing Games: An Experimental Study,” *American Economic Review*, 96 (5), 1737–68.

———, ———, and Bruno Broseta (2001), “Cognition and Behavior in Normal-Form Games: An Experimental Study,” *Econometrica*, 65 (5), 1193–1235.

Gentzkow, Matthew A. (2007), “Valuing New Goods in a Model with Complementarity: Online Newspapers,” *American Economic Review*, 97 (3), 713–44.

Haile, Philip A., Ali Hortacsu, and Grigory Kosenok (2008), “On the Empirical Content of Quantal Response Equilibrium,” *American Economic Review*, 98 (1), 180–200.

Haruvy, Ernan, Dale Stahl, and Paul Wilson (2001), “Modeling and Testing for Heterogeneity in Observed Strategic Behavior,” *Review of Economics and Statistics*, 83 (1), 146–57.

Ho, Teck H., Colin Camerer, and Keith Weigelt (1998), “Iterated Dominance and Iterated Best-Response in *p*-Beauty Contests,” *American Economic Review*, 88 (4), 947–69.

———, Noah Lim, and Colin F. Camerer (2006), “Modeling the Psychology of Consumer and Firm Behavior with Behavioral Economics,” *Journal of Marketing Research*, 43 (August), 307–331.

Hortacsu, Ali and Steven L. Puller (2008), “Understanding Strategic Bidding in Multi-Unit Auctions: A Case Study of the Texas Electricity Spot Market,” *RAND Journal of Economics*, 39 (1), 86–114.

Keane, Michael (1994), “A Computationally Practical Simulation Estimator for Panel Data,” *Econometrica*, 62 (1), 95–116.

Lim, Noah and Teck-Hua Ho (2007), “Designing Price Contracts for Boundedly Rational Customers: Does the Number of Blocks Matter?” *Marketing Science*, 26 (3), 312–26.

McKelvey, Richard and Thomas Palfrey (1995), “Quantal Response Equilibria for Normal-Form Games,” *Games and Economic Behavior*, 10 (1), 6–38.

Nagel, Rosemarie (1995), “Unraveling in Guessing Games: An Experimental Study,” *American Economic Review*, 85 (5), 1313–26.

Netzer, Oded, James Lattin, and V. Seenu Srinivasan (2008), “A Hidden Markov Model of Customer Relationship Dynamics,” *Marketing Science*, 27 (2), 185–204.

Reinganum, Jennifer F. (1981), “Market Structure and the Diffusion of New Technology,” *Bell Journal of Economics*, 12 (2), 618–24.

Seim, Katja (2006), “An Empirical Model of Firm Entry with Endogenous Product-Type Choices,” *RAND Journal of Economics*, 37 (3), 619–40.

Soberman, David A. (2007), “Marketing Agencies, Media Experts, and Sales Agents: Helping Competitive Firms Improve the Effectiveness of Marketing,” working paper, Rotman School of Management, University of Toronto.

Stahl, Dale O. (1993), “Evolution of Smart$_n$ Players,” *Games and Economic Behavior*, 5 (4), 604–617.

——— and Paul W. Wilson (1994), “Experimental Evidence on Players’ Models of Other Players,” *Journal of Economic Behavior and Organization*, 25 (3), 309–327.

Storn, Rainer and Kenneth Price (1997), “Differential Evolution: A Simple and Efficient Heuristic for Global Optimization over Continuous Spaces,” *Journal of Global Optimization*, 11 (4), 341–59.