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Guest Editorial

Competition and Game Theory

"Game theory is hot," the *Wall Street Journal* (1995, p. A19) has proclaimed. As game theory has swept through economics and related disciplines, one of its many payoffs has been new insights into that most fundamental of business processes—competition.

The method by which products are sold is often taken for granted in the marketing literature. Much is to be gained, however, from comparing alternative selling formats. We outline some models that generate insights into how competition works and how to price products under competitive conditions.[1]

The classical theory of perfect competition, as developed by economists from Adam Smith to Alfred Marshall (Stigler 1965), takes a reduced-form approach: It depicts the outcome of competition, but not the activity of competing. Much of what is interesting and important about competition is hidden in the background. The *Oxford English Dictionary* defines competition as "rivalry in the market, striving for custom between those who have the same commodities to dispose of." A perfect competitor, as depicted in economics textbooks, does not do any competing according to this definition. "Striving for custom" implies a dynamic process, the action of competing. A perfectly competitive firm does not pay attention to what any of the other firms in the industry are doing. Instead, it passively accepts the going market price. Any "rivalry in the market" is assumed away. The new game-theoretic models, in contrast, view competition as a process of strategic decision making that is performed under uncertainty; they depict people and firms engaged in competition. For example, an important aspect of competition neglected in the models of perfect competition is the public revelation of private information.

Competition helps sellers price items when the buyers' willingness to pay is unknown. Being faced with competition on the other side of the market is a source of bargaining power. Competition can be used to generate incentives for productive effort. The game-theory models of competition do not supplant the textbook wisdom; they supplement it. They do not undermine the crucial finding that, under certain precisely specified conditions (Debreu 1959), competition sets prices correctly, thereby generating an efficient allocation of resources. What the new models do is add microdetail to the classical theory, while modeling, among other things, how prices become set through competition.[2]

DESIGNING NEW COMPETITIVE MECHANISMS

The ultimate test of a theory of markets, and one that is more stringent than confronting the theory with data from existing markets, is to use it in designing innovative market mechanisms. The new theoretical understanding of how competitive markets function, together with the use of high-speed computers, has made possible the invention of new markets (McAfee and McMillan 1996b). Electronic markets can allocate goods efficiently in circumstances in which simple supply and demand works poorly, because goods are idiosyncratic and differentiated, there are multiple goods with synergies among them, buyers' preferences are ill-behaved by the criteria of standard theory, or there is a need to match particular buyers and sellers. Economic theory has been used in the design of competitive bidding mechanisms to sell spectrum licenses (McAfee and McMillan 1996a), devise railroad schedules (Brewer and Plott 1996), and trade electric power and long-term contracts for the supply of industrial chemicals (Chao and Wilson 1995). The new competitive mechanisms permit decentralized decision making in situations in which decisions previously had been made centrally, and inefficiently.

Other uses for the new electronic markets also might emerge. One possible use relevant to marketing is by a firm buying inputs from other firms. Conventional procurement specifies the level of assembly at which components are to be purchased. If, instead, a simultaneous auction mechanism were used, the procuring firm could define the components finely and have the potential suppliers bid component by component, with the possibility of winning several contracts and thus supplying a bundle of components. Each supplier would reveal its economies of scope (lowered per unit cost of doing related production) by the set of components for which it bid.

Another possible application is in the sale of a multidivisional corporation. The simultaneous auction could allow buyers to bid division by division. The bidders could thereby express their ideas on which parts of the firm fit together and which should be spun off to create more efficient enterprises. The uses of the new auction forms have just begun.

The Federal Communications Commission's spectrum-license auctions and other new auction forms were designed

[1]Exceptions in marketing that compare the performance of different trading mechanisms include articles by Coughlan and Wernerfelt (1989), McGuire and Staelin (1983), and Wernerfelt (1994).

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[2]For more on the new concepts of competition, see Vickers (1995). On theories of competitive bidding, see McAfee and McMillan (1987), McMillan (1992, Chapter 11), Milgrom (1989), and Wilson (1992).

Journal of Marketing Research
Vol. XXXIII (August 1996), 263–267

using ideas derived from game-theory models. We introduce some of the main ideas emerging from these models.

COMPETITION REVEALS HIDDEN INFORMATION

The simplest setting in which to study competition is in the sale of a single item by an open outcry auction. What is learned from this can be generalized to richer and more complex competitive mechanisms.

Suppose that each of the competing bidders attaches a different, subjective value to the item for sale. They all know exactly how much it would be worth to themselves to own it but not how highly any of the others values it. (This is called the *independent-private-values case.)* The seller is ignorant of the bidders' valuations, so setting a price for the item is unlikely to be an effective strategy. Each bidder's rational strategy in the open auction is to be willing to bid until the price passes his or her valuation. Rather than let the item sell to someone else for a price below his or her valuation, it is better to bid and possibly obtain a profit. Conversely, should the price go above the bidder's valuation, winning would mean paying more than the item's value; bidding above the valuation is unprofitable. The selling price, therefore, equals (approximately) the second-highest valuation among the bidders. The bidding process reveals information, because the seller initially may have known nothing about the value of the item. After the auction, the price gives the seller an estimate of the item's value. It is an underestimate, because the price is the second-highest valuation, but if the number of bidders is reasonably large, the price reached in the auction can be expected to come close to the winning bidders valuation.

Bidding competition can also serve to reveal another kind of information. Let us change the nature of the uncertainty about valuations so as to make valuations objective rather than subjective. The item in this model (the *common-value case*) is worth the same no matter who wins it. At the time of the bidding, however, no one knows what this value is. Each bidder has an estimate of value, which is subject to error. (This model, for example, can apply to bidding for an oil well, in which the common uncertainty concerns the amount of oil.) Bidders are now faced with the risk of the "winner's curse": The winner is likely to be the bidder who has most overestimated the item's value. There is a tendency, therefore, for the winning bidder to overbid. Bidders can avoid the winner's curse by bidding cautiously, recognizing they will win only if they have relatively high estimates, and by discounting their estimates.

The winning bid, then, on average is below the item's true but unknown value; but with more and more bidders, the price approaches the true value, and with a large number of bidders, it comes extremely close to it (Wilson 1977; Milgrom 1979). This is a remarkable result. No one person knows the true value; each person's estimate may be highly imperfect. The price, however, is an accurate value estimate. The competitive process serves to aggregate the scattered information so that the market price is a more accurate estimate of value than any one person's estimate.

The demand-revealing character of auctions has a direct application in marketing. When contemplating whether to introduce a new product or when setting the price for a product about to be introduced, a firm must know consumers' willingness to pay for the new product. Traditional methods of market research include surveys, focus groups, and pretest markets. An alternative method for revealing demands for a new product, which has been implemented experimentally by Hoffman and colleagues (1993), has customers bidding in an auction. If the auction's pricing rules are well designed, so as to induce bidders to reveal their preferences correctly, then the auction can, in principle, be a useful tool of market research, supplementing the more traditional tools.

Auction theory generates practical recommendations for an organizer of a bidding competition. Open bidding, rather than sealed bidding, should be used because it encourages higher bids. A minimum price should be set—high enough to force a high bid but not so high that no one is likely to bid. Royalties or other forms of revenue sharing might be used to make the bidding more competitive. The seller should release any information he or she has that is relevant to the bidders' assessment of the item's value, because doing so increases the competitiveness of the bidding and reduces the risk of cautious bidding, which the winner's curse induces.

COMPETITION WORKS BETTER THAN BARGAINING

Competition is a good substitute for bargaining skill.[3] Consider a seller of an indivisible item who has the choice of selling by means of either bargaining with a single buyer or offering the item for competitive bidding between two potential buyers. In the bargaining case, we allow the seller to be a determined, ruthless negotiator, who is well informed in that, though not knowing the buyer's valuation exactly, he or she does know the range of possible valuations. In the bidding case, the seller passively accepts bids without setting a minimum price, knowing nothing about even the range of possible bidder valuations.

To be specific, suppose that a buyer's valuation could be either \$40 or \$100, each with equal probability; only the buyer him- or herself knows which it actually is. The seller attaches no value to the item if it is unsold. Under bargaining, the best the seller can do is set a take-it-or-leave-it price of \$100, selling the item only if the buyer happens to have the higher valuation (with probability .5), for an expected profit of \$50. (Because the seller is not risk averse, he or she will prefer this to the alternative of pricing the item at \$40 and being sure of selling it for a profit of \$40.) Under bidding, on the other hand, there are four equally likely possibilities for the two bidders' valuations: (\$40, \$40), (\$40, \$100), (\$100, \$40), and (\$100, \$100). Bidding competition drives the price up to the second-highest valuation, \$40 in the first three cases and \$100 in the fourth, so the seller's expected profit is \$40 × ¾ + \$100 × ¼, which equals \$55. The price reached by competitive bidding, on average, is higher than the negotiated price.

The intuition behind this result (which is due to Bulow and Klemperer 1996) is that a good bargainer functions like an artificial competitor. The bargainer's main source of bargaining power, the threat to refuse to sell the item if the price is not high enough, is analogous to going to another bidder in the competitive case. Yet, a real competitor is more effective than a fake one. The result generalizes to describe varying degrees of competition: An extra bidder helps the seller, because the seller is better off with n + 1 bidders and simply selling to the

[3]For an introduction to game-theoretic models of bargaining, see McMillan (1992, Chapters 5 and 6).

highest bidder than with n bidders and actively stimulating the bidding competition by setting a minimum price.[4]

The seller receives a higher price, therefore being a passive accepter of bids from competing potential buyers rather than a tough, clever bargainer without buyer competition. Moreover, accepting bids puts much less of a burden on the seller's knowledge and abilities than being a negotiator. In the bargaining game, the seller must know the range of possible buyer valuations in order to be able to compute the best price to charge (or excel at deducing this information from the process of bargaining), whereas in the bidding game, the seller needs no information about valuations and does not need to put any thought into the selling strategy. To implement the optimal bargaining strategy, the seller must be able credibly to commit him- or herself to the $100 price demand, even if the seller discovers that the buyer's valuation is $40 through the buyer's rejecting the offer. The seller, on failing to negotiate a price of $100, will be tempted to cut the price to $40; but any such willingness to undercut reduces the seller's initial bargaining power, because the buyer, if he or she values the item at $100, would now be tempted to wait for a price reduction (McAfee and Vincent 1995). In the bidding game, in contrast, the seller's commitment is merely to sell to the highest bidder, which is a much easier commitment to maintain. Competition, therefore, yields higher prices and economizes on knowledge, computation, and commitment abilities.

A firm's purchasing officer, in procuring some component, has a choice between negotiating with a sole supplier and organizing a bidding contest among several potential suppliers. There may be particular reasons for dealing with a single supplier (McMillan 1990); for example, as a reward for that supplier's good performance in the past. However, the foregoing result suggests that, in the absence of any such overriding consideration, the purchasing officer should use competition. To get a good price, the seller should place more faith in the power of competition among alternative suppliers than in his or her own negotiating skill.

COMPETITION CREATES EFFORT INCENTIVES

Competition can be used to create incentives for productive effort. For example, salespeople compete to win a prize, such as a trip to Hawaii; assistant professors compete for limited tenure slots; corporate vice-presidents compete to be promoted to chief executive officer; and the U.S. Department of Defense regularly uses tournaments to choose suppliers. These contests, or tournaments, which make remuneration depend not only on people's own performance but also on that of their peers, can be structured as incentive devices (Lazear and Rosen 1981).

In environments with several employees, tournaments provide a way to reward effort without requiring that the efforts of the employees be directly monitored. Tournaments reward the employee or agent with the largest output; and output is generally viewed as arising from some combination of luck, effort, and skill.

To be specific, suppose two agents, A and B, each produce an output Q according to $Q = E + u$, where E is the effort the agent exerts and u is a random variable representing the agent's luck. The personal cost to the agent of exerting the effort is C(E), and there are diminishing returns to effort. A prize of W is offered to the agent who produces the most output; the other agent receives nothing. Agent A wins the prize if he or she produces more than Agent B does (i.e., if $Q_A > Q_B$). This occurs if $E_A - E_B > u_B - u_A$. We represent the probability distribution of the random terms by $G(u_B - u_A)$: This formulation incorporates the degree of correlation of the two agents' luck. The probability of Agent A's winning is then $G(E_A - E_B)$, and Agent A's expected net return from exerting effort is therefore $W \cdot G(E_A - E_B) - C(E_A)$. Maximization of this expression by Agent A with respect to E_A yields Agent A's optimal effort level E_A^* (for any given effort E_B by B) and satisfies the condition $W \cdot G(E_A^* - E_B) = C'(E_A^*)$, where C′ denotes marginal cost, and g denotes the probability density function corresponding to G. This equation provides Agent A's best response E_A^* to Agent B's effort E_B. It has the simple intuition that Agent A's marginal cost of effort is equated to the value of the increased probability of the prize, W, which is created by an increase in effort. Agent B has a similar best-response function. The symmetric Nash equilibrium has each agent winning with 50% probability and each exerting the effort level E* that satisfies $W \cdot g(0) = C'(E^*)$. Assuming there is an increasing marginal cost of effort, the equilibrium level of effort increases as the size of the prize W increases and decreases as the amount of luck involved in the outcome, measured by the reciprocal of g(0), increases. The term g(0) represents the likelihood that the agents have equal luck in generating output when efforts are equal, so that when g(0) is large, luck plays a small role, because it is likely the agents had equal luck.

The larger the prize, therefore, the more effort it engenders. The designer of the incentive scheme can elicit from the two agents whatever effort he or she wishes by appropriately setting the prize, W. The size of the prize that is needed reflects the extent to which luck affects output. If the randomness in measured performance is large, that is, g(0) is small, then the prize must be large if it is to generate much effort from the agents. If luck has a big effect on output, the agents will tend to sit back and rely on luck to earn them the prize; therefore, a large prize is needed to counter this incentive. If, on the other hand, an agent's output is closely related to effort, with little variability uncontrolled by the agent, that is, g(0) is large, a smaller prize will suffice. Considerable disparities across ranks in employees' pay might be explained by the effort incentives they induce at the lower ranks, which is a consequence of tournaments for promotions.

Tournaments are already familiar devices for inducing effort; they often provide free vacations, new cars, and so on to the best salespeople. Tournaments are a good means of motivating a sales force, especially in circumstances in which little is known about the difficulty of selling a product, as would arise with the introduction of a new product. The advantage of a tournament over paying commissions is that with commissions, the employer must estimate how many units are likely to be sold in order to set reasonable compensation levels. With a tournament, the employer can pay a minimal amount and use the tournament as the main

[4]Bulow and Klemperer (1996) show that this result holds in far more general settings than here, though a caveat is needed. The conclusion that the expected price is higher with two bidders and a passive seller than with a single buyer and a committed seller assumes that the probability distribution function of valuations satisfies the *monotone-hazard-rate condition;* this will hold in most, but not all, cases.

reward for effort. The advantage is that the tournament compensation remains fixed whether selling the product turns out to be easy or difficult. Thus, tournaments should be more heavily relied on when the demand for the product is uncertain (for an empirical review of sales force compensation methods, see Coughlan and Narasimhan 1992).

Game-theoretic analysis suggests ways of optimizing tournaments to maximize firm profits. Tournaments may be improved in several ways. First, it may be desirable to limit entry into the tournament, so as not to dilute the incentive effects of the prize: If too many people enter the tournament, no one person stands much of a chance of winning (Taylor 1995). In such cases, it may be desirable to make entry into the tournament itself be determined by a competitive process, using bidding as a screening device and selecting the most qualified employees (Fullerton and McAfee 1996).

Second, firms may want to construct multiple tournaments, thereby inducing employees to choose the tournament in which to participate. The advantage of running several tournaments simultaneously is that employees with different skills choose the tournament, and hence the products on which to focus, on the basis of their own skill level and comparative advantage. For example, a large real-estate company might wish to run two separate tournaments for its agents: one a competition for the agent who can bring in the most house buyers, the other for the agent who can bring in the most house sellers. This permits employees to specialize in the activities in which they excel.

Third, the employer can use bidding to set the level of tournament compensation. For example, a real-estate company might need to concentrate more effort on bringing in new buyers; one way of doing so is to choose a number n of people on which to focus their energies for obtaining buyers and to allow bidding for the size of the tournament price, which is determined by the n^{th} lowest bid. The tournament must be restricted to the n employees submitting the lowest n bids, with the remaining employees being ineligible for the prize. This mechanism reveals, in the competition to determine participation in the tournament, the level of compensation necessary to induce employees to focus their energies on bringing in new buyers.

COMPETITIVE MECHANISMS ARE ROBUST

Competitive mechanisms tend to be robust: They work well even in the face of mistakes or irrational behavior by the market participants. This theme runs through the new models of competition, though it has yet to be fully explored. A well-designed (or appropriately evolved) competitive mechanism works efficiently even when the people whose behavior it determines lack the knowledge and computational abilities that are usually assumed in economic modeling.

The outcome of market competition is more likely to conform with game-theoretic rationality than with the outcome of a bilateral negotiation, according to the experiments of Roth and colleagues (1991). The competitiveness of the market process constrains participants in their choice of strategies, so the outcome is usually the game-theoretic equilibrium, whereas the indeterminacy of bargaining[5] leaves room in which bargainers can engage in complicated game-playing, with the result that outcomes are more idiosyncratic.

[5]That is, there is a range of (Pareto efficient) outcomes that are Nash equilibria but are not perfect equilibria.

Different competitive mechanisms differ in their robustness to changes in the environment, mistakes in setting prices of incentive levels, and other features of the marketplace. An open auction, in which bidders call their bids and go on raising them until only one remains, is more robust than a sealed-bid auction, in which bidders make a single bid in ignorance of their rivals' bids. This is because in the open auction bidders can learn from the others' bids, whereas in the sealed-bid auction they cannot. To make a good bid decision in the sealed-bid auction, a bidder must conjecture the others' bid decisions. Bad outcomes—either losing by bidding too low or overpaying through bidding higher than is necessary to win—can result from incorrect conjectures. In the open auction, the bidder's decisions are easier, and the outcome is more controllable. For these reasons bidders typically say they prefer open auctions to sealed-bid auctions, even though, according to auction theory, open auctions produce higher prices.

The rules for competition, if well designed, can ensure that a market produces an allocation that is close to efficient even with traders who are incapable of calculating what is in their interest, according to experiments by Gode and Sunder (1993). The wisdom of the market compensates for the market participants' lack of rationality.

Competitive tournaments, as was noted previously, provide effort incentives. Yet, they are not the only way of generating incentives; instead, people could simply be paid according to their own performance. Tournaments are more robust than the direct pay-for-performance method, because they economize on the employer's information gathering. Observing whether one person has done a better job than another may be easier than precisely measuring each person's output. Also, if the randomness that affects output is correlated across agents, the tournament filters out the common randomness, thus permitting more accurate inferences about each agent's effort.

CONCLUSION

The new game-theoretic understanding of competition is valuable for marketing in several ways. It provides a better understanding of how to motivate the sales force—by getting employees to compete for prizes and pay; a similar theory applies to research and development or product design competitions. It permits the design of new selling methods, such as the spectrum auctions used by the Federal Communications Commission. It provides a supplement to the traditional survey approach for assessing the value of new products. It provides insights into subcontracting and purchasing methods, and in particular, the disadvantages of sole-source negotiation when competition is possible. An important role for marketing arises in inducing competition—how does a firm go about attracting participants to new, and often unfamiliar, competitions? Further research is both necessary and important. Finally, the game-theoretic approach emphasizes the reaction of rival firms, as well as consumers, to changing marketing strategy. We close with some observations on rival firms' reactions, which we apply to product-line pricing.

When several firms offer identical products, the competition focuses on price, and the result is prices close to marginal cost. Thus, offering the same product as a competitor is a bad strategy for a firm. Firms would like to offer better

products than their rivals, because a superior product provides a natural advantage. But when offering a superior product is not an option, it may be better to offer an inferior product rather than an identical product. By offering an identical product, a firm induces its rival into price cutting to match the firm's price—a process that leads to low prices and low profits for both. In contrast, by offering an inferior product, the firm does not induce such a severe reaction from the rival, and instead carves out the low end of the market for itself, which results in higher profits for both firms.

For example, when Hewlett-Packard introduced the HPIIp Laser Printer, IBM responded with a similar product, the IBM LaserPrinter E (see Deneckere and McAfee 1996). The LaserPrinter E was a lower-quality product than the IBM LaserPrinter already for sale. The effect of the introduction of the LaserPrinter E was severe price competition in the low end of the laser printer market, which in turn eroded the profits on the high end of the market dominated by the IBM LaserPrinter, because the low end became more attractive to consumers.

Although there are advantages, such as consumer confidence and one-stop shopping, to offering a full product line, it is important to realize that market power and resulting profits come from differentiation of products. Identical products induce strong price competition. In pricing products and choosing which products to offer, firms should forecast their rivals' and customers' responses; that is, firms should think game-theoretically.

A firm introducing a new product into the market may choose to create competition in this new product. It is often necessary for users to make some product-specific investments before a new product can be adopted. Creating competition in the supply of the new product serves as a form of assurance for the users before they incur the costs of the specific investment: Competition is a means of committing to low prices in the future (Shepard 1987; Wernerfelt 1994). Sony retained monopoly production of the Beta video cassette recorder format, which probably accounts for the competitively supplied VHS's defeat of Beta. Similarly, Intel's licensing of production of the early 8086 microprocessors to Advanced Micro Devices resulted in a commitment to lower prices through competition, which accounts for the dominance of the Intel-based personal computer over its rival, MacIntosh. Paradoxically, in some instances, creating competition is the best means to creating market power.

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