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MODELING, GAME THEORY, AND STRATEGIC MANAGEMENT

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This paper examines the potential usefulness of game-theoretic modeling for the development of theory in strategic management. It is argued that there is significant potential for the development of 'metaphorical' models that capture the broad qualitative features of settings involving strategic interactions. The paper discusses the positive attributes of mathematical modeling, the nature and role of game-theoretic modeling, and its potential for contributing to empirical work and to providing advice to managers.

INTRODUCTION

During the 1970s and 1980s considerable effort was devoted to applying game-theoretic techniques to the analytic modeling of issues in industrial economics. The sophistication and breadth of the models described in *The Handbook of Industrial Organization* or in Jean Tirole's *The Theory of Industrial Organization*, bear testament to the extent of that effort.

Many of the issues examined in that body of work are of direct relevance to competitive strategy, the branch of strategic management concerned with what one might call 'external' strategy issues, i.e. the firm's strategy *vis-à-vis* its rivals. These include issues such as the importance of first-mover advantages and the role of commitment in staking out a market position;¹ reputation formation and exploitation;²

signaling;³ and the strategic control of information more generally (Fudenberg and Tirole, 1986).

While most of the models have focused on external strategy issues, recently these tools have been turned increasingly to other questions of direct relevance to strategic management having to do with the internal organization of the firm and the appropriate scope of its activities. These include questions relating to the vertical scope of the firm's activities (Grossman and Hart, 1986); and the effect of incentives on the optimal horizontal scope of the firm (Jensen, 1986); and the appropriate breadth of the firm's business and corporate strategies (Rotemberg and Saloner, 1990b).⁴

Finally, issues at the intersection of these 'internal' and 'external' orientations constitute a growth area within economics. The issues here include the effect of incentive schemes within the

Key words: game theory, rationality, modeling

¹ See Lieberman and Montgomery (1988) for an overview of first-mover advantages and Schmalensee (1978, 1982), and Spence (1977, 1981) for specific examples. Dixit (1980) and Judd (1985) contain analyses of the importance of the ability to make commitments.

² See Weigelt and Camerer (1988) and Kreps and Spence (1984) for overviews, and Kreps (1990a), Rotemberg and Saloner (1986, 1990a), and Green and Porter (1984) for examples. The work of Kreps and Wilson (1982), Milgrom

and Roberts (1982b), and Kreps *et al.* (1982) is discussed in Saloner (1992).

³ See Spence (1974) for the development of the theory and Milgrom and Roberts (1982a) discussed in Saloner (1992) for an application to entry deterrence.

⁴ In their forthcoming book, *Economic Organization and Management*, Milgrom and Roberts provide a detailed analysis of many of these issues and describe numerous implications for strategic management.

firm on product market competition;⁵ the ability to use vertical integration to achieve competitive advantage (Ordover, Saloner, and Salop, 1990; Hart and Tirole, forthcoming, and Bolton and Whinston, 1989); and the effect of distribution channel design on competition (Coughlin and Wernerfelt, 1988; Moorthy, forthcoming, and Bonanno and Vickers, 1988).

Despite the relevance of these issues to strategic management, the impact on that field has mainly been through 'importing' relevant implications from economics. The question arises, however, as to whether there isn't a more direct role for game-theoretic modeling within strategic management, as a tool used by scholars who regard strategic management as their primary field.

This question is complicated by the difficulty that once a model has the trappings of microeconomics⁶ there is a tendency to define it as being about economics rather than strategic management. If, however, strategic management is defined by a set of research questions or by the subject matter of the field, however, then this problem does not arise. Models of strategic groups, generic strategies, or how organizational structure influences strategy, all fall within the domain of strategic management whether they have the trappings of microeconomic models or not. It is the prospect of the development of such models that we have in mind below.

This question of whether there is a role for game-theoretic modeling within strategic management really has two components. The first is whether there is a role in strategic management for *modeling of the microeconomic variety* at all, whether game-theoretic or not. The second, which arises only if the first is answered in the affirmative, is whether such modeling should be game-theoretic. Most of the attention among strategic management scholars seems to be focused on this latter question. This is probably, at least in part, a spillover from the debate within the economics profession itself about the relative merits of the more recent

game-theoretic modeling and the 'older' standard neoclassical methods.⁷

However, it is probably also due in part to the fact that some observers within strategic management are troubled by the complexity of the reasoning of which the agents whose behavior is being analyzed are assumed to be capable. For example, Rumelt, Schendel, and Teece (1990) write:

Rational models of competitive interaction posit players who engage in very subtle and complex reasoning. Yet our common experience is that decision-makers are far less analytic and perform far less comprehensive analyses than these models posit. If one is a player, is it really 'rational' to posit such complex behavior in others? (p. 9)

The degree of rationality assumed in game-theoretic models is often much greater than in other economic models. In game-theoretic models each firm's optimal action depends on what it believes its rivals will do. In order to decide what to do itself, the firm must put itself in its rival's shoes and analyze the situation from its rival's perspective. The analysis therefore requires assumptions about the rival's rationality, as well as the assessment of the rival's belief about one's own rationality, and so on. These assumptions are particularly striking in a field like strategic management which tolerates a wide variety of behavioral assumptions.

The increased burden the assumption of rationality is asked to bear in game-theoretic models can be seen by contrasting duopoly theory with the theories of perfect competition and of monopoly. In the case of monopoly the firm faces a 'simple' optimization problem. The situation is even more straightforward for a perfectly competitive firm which, as a price-taker, only has to ascertain whether or not it can profitably produce *any* quantity at the equilibrium price. The duopolist's optimal decision, on the other hand, depends on what its rival will do.

In order to make the critique of the rationality assumption in game-theoretic models even more concrete, consider the following game. In this

⁵ See Fershtman and Judd (1987), discussed later, for example.

⁶ Rational decision-makers with well-defined objective functions and possible actions.

⁷ See, for example, the debate between Fisher (1989) and Shapiro (1989) in the *Rand Journal of Economics*.

game you choose 'top' or 'bottom' while your opponent simultaneously chooses 'left' or 'right'. Your actions lead to the pay-offs in Table 1 where, as usual, the first number in each cell is the 'row player's' (your) payoff and the second is the 'column player's'. Thus, for example, if you choose 'top' and your opponent chooses 'left', you receive 1 and your opponent receives 0 (where higher numbers denote more desirable outcomes; perhaps the numbers represent dollars or a measure of utility).

To the casual observer the most striking feature of these payoffs is the '-1000' that you receive if the 'bottom left' outcome occurs. From a game-theoretic point of view, however, the most striking feature is the fact that choosing 'right' is the best strategy for your opponent regardless of what you do: he earns 1 if he chooses 'right' and 0 if he chooses 'left'.⁸

Given the 'compelling logic' that your rival should play 'right', your own choice boils down to choosing 'top' and receiving 1 (the 'top right' outcome) or choosing 'bottom' and receiving 2 ('bottom right'). Clearly you 'should' choose 'bottom'. Game theory predicts the 'bottom right' outcome.

Notice, however, that you stand to lose a great deal (1000) if you behave as game theory predicts you will while your opponent does not. A 'mistake' by your opponent would not be very costly to him, but it would be extremely costly to you. Indeed, the cost to your opponent of his making a mistake could be arbitrarily small without changing the structure of the argument.⁹

Table 1. The 'rationality' game

		Opponent	
		Left	Right
You	Top	1,0	1,1
	Bottom	-1000,0	2,1

⁸ In the language of game theory, playing 'right' is a *dominant strategy*.

⁹ To see this imagine replacing the zeroes in the above table by $1-\epsilon$ and consider ϵ to be as small as you like. Now imagine what you would in fact choose to do if you were 'playing' this game against a variety of different opponents: David Kreps, a fourth grader, an average undergraduate, the CEO of a typical U.S. firm . . . A somewhat cautious player might choose to play 'top' in these circumstances in which case she is assured of earning at least 1. A conservative strategy of

Given the degree of rationality assumed in game-theoretic models, can they usefully be employed in strategic management? The answer to this question must depend on the role these models are expected to play. One role is a rather literal one in which the model is supposed to mirror an actual managerial situation and the desired output is an exact prescription as to what action to take: how much capacity to install, how much to produce, how to position one's product, etc. In such settings, as in the rationality game, the burden on the rationality assumption may be quite severe.

We argue in the next section, however, that there are many games, including many of the kind that arise in strategic management, where the degree of rationality required does not strain the limits of plausibility. We illustrate this by an examination of the popular Cournot model, which in many respects provides the best case for the plausibility of a literal model.

In the third section, however, we argue that literal interpretations of game-theoretic models are largely irrelevant and that the debate about whether firms would play the Cournot game as game-theorists would is largely academic. Rather we argue that the appropriate role for microeconomic-style modeling in strategic management generally, and for game-theoretical modeling in particular, is not literal but rather is metaphorical. The nature and role of metaphorical modeling, its potential for contributing to strategic management, and the lower burden placed on the rationality assumption in such settings is discussed there.

In the fourth section we discuss the distinction between the profit-maximization and rationality assumptions. The profit maximization hypothesis has two parts: that firms maximize 'something', and that the 'something' is profits. The rationality assumption is only concerned with the first of these, *i.e.* that firms attempt to maximize

this kind is called a 'maximin strategy' since it asks the question 'what is the minimum I can earn with this action?' and selects the action that results in the largest of these minima. In the present case if both players used maximin strategies the outcome 'top right' would result. A maximin strategy is conservative but not maximizing and therefore not 'rational'. If you knew your opponent was using a maximin strategy you would prefer to play 'bottom' to using your own maximin strategy.

something although not necessarily profits.¹⁰ Indeed, we show that it may sometimes be in a profit-maximizing firm's interests to convince its rivals or employees that it (or its managers) are interested in maximizing something other than profits.

In the fifth section we examine the role that game-theoretic modeling can play in providing advice to managers and in conducting empirical work. Finally, the last section contains concluding remarks.

A LITERAL INTERPRETATION OF GAME-THEORETIC MODELING: RATIONALITY IN THE COURNOT MODEL

In this section we take a literal approach to game-theoretic modeling. We examine the role that the rationality assumption plays in a game that is beloved of many industrial organization economists: Cournot duopoly, perhaps the most frequently applied game in industrial organization. Our interest is not in the Cournot game *per se*, however. We look at it because it illustrates the nature and role of rationality in a fairly broad class of the applications of game theory of interest to strategic management.

In the game first considered by Augustin Cournot more than 150 years ago, two firms simultaneously choose how much of a homogeneous good to produce so that each firm must make its output decision in ignorance of the other's. The firms' chosen production is 'sent to the market' where it fetches the highest price at which the combined output of the firms can be sold.

In many respects the Cournot model represents the 'best case' for literal game-theoretic modeling. It is a 'one-shot' game, (i.e. the firms meet in this way only once) so that 'repeated play' considerations do not arise; there is no asymmetric information, and, as discussed below, there is a unique equilibrium outcome which does not involve mixed strategies.

To be concrete we assume a particular form of the demand function, that is the highest price

at which a combined output of the two firms of Q units can be sold can be represented by $P = a - Q$. We suppose further that it costs a firm cq_i to produce q_i units, so that c is the (constant) per unit cost of production.

How 'should' a firm that wants to maximize profits 'play' this game? The firm's optimization problem and its 'solution' are deceptively easy to write down. Denoting the firm's own output by q_i and its belief about what its rival will produce by q_j , firm i 's profit can be written as:

$$\pi_i = (a - q_i - q_j - c)q_i \quad (1)$$

Differentiating with respect to q_i , the 'solution' is:

$$q_i = [a - q_j - c]/2. \quad (2)$$

Equation 2 and the corresponding equation for firm 2 are depicted in Figure 1.

Predicting outcomes

To obtain a prediction as to what each firm will in fact produce in the Cournot setting, one must go considerably further than Equation 2. Each firm must predict what its rival will do. But how should it do this? The 'standard' solution offered by game theory, the Nash Equilibrium, does not specify the logic by which a firm should decide what it should do, but rather 'leaps' directly to the solution by specifying desirable properties that strategies should possess in order to be

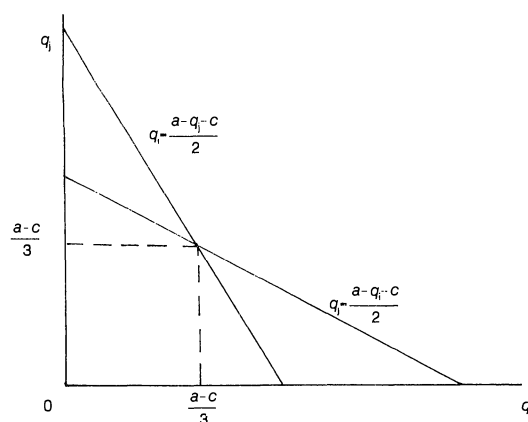


Figure 1. Best response functions in the Cournot game

¹⁰ The question of whether firms maximize profits has received considerable attention elsewhere (see Kreps, 1990b for a discussion).

'equilibrium' strategies.¹¹ In particular, each player's strategy must be optimal given the other's strategy.

In this setting this means that for $\{q_1^*, q_2^*\}$ to be a 'solution' to the game it must be the case that $q_1^* = [a - q_2^* - c]/2$, i.e. firm 1's strategy is optimal given q_2^* , and $q_2^* = [a - q_1^* - c]/2$, i.e. firm 2's strategy is optimal given q_1^* . The only way both of these conditions can hold is if $q_1^* = q_2^* = (a - c)/3$.

Because of the way in which it is defined, the Nash Equilibrium has the attractive property that if, *ex post*, one observes that the Nash strategies have been played, it is very easy to rationalize the firms' behavior. Given what firm 2 did, firm 1 behaved optimally and *vice versa*. Put differently, each firm's belief about what its rival would produce turned out to be correct. Moreover, this could only be said about strategies that formed a Nash Equilibrium since if the firms did not both play their Nash strategies, *ex post* both would regret not having taken a different course of action.

As pointed out above, however, the Nash Equilibrium does not describe how the firms come to have the 'correct' beliefs in the first place. In the case of the Cournot game, given profit-maximizing objectives and rationality on the part of the players, it turns out that logic alone is enough to derive the solution. To see this note from (2) that firm *i*'s optimal output is decreasing in q_j the amount that it believes that its rival will produce. Therefore the most that firm *i* should ever produce can be derived from (2) by setting $q_j = 0$, i.e. firm *i* should never produce more than $(a - c)/2$, the amount it would produce if its rival stayed out of the market. But if firm *j* knows that firm *i* won't produce more than $(a - c)/2$ then it should produce at least $[a - \{(a - c)/2\} - c]/2 = (a - c)/4$. Knowing this, firm *i* should produce at least $[a - \{(a - c)/4\} - c]/2 = 3(a - c)/8$. This reasoning converges (with

infinitely many iterations) to the conclusion that each firm should produce $(a - c)/3$.¹² At each stage of the reasoning, a dominance argument is applied.¹³

The fact that the Cournot game can be 'solved' through the pure logic of iterated dominance in this way should not give one enormous comfort. Recall, for example, that the 'rationality game' discussed at the beginning of this section was solved there in the identical manner. Even though iterated dominance is a strong argument by game-theoretic standards, the fact that the argument must be repeated infinitely often may make one skeptical about the ability of the 'typical' player to apply it successfully.

Robustness

There is, however, a sense in which one should feel much more confident in playing the Cournot-Nash strategy than in playing 'bottom' in the 'rationality' game because of the robustness of Cournot to 'small mistakes'. Suppose, for example, that the firm believes that the rival is 'trying' to behave as game theory suggests a 'rational' opponent should, but that the rival is not very good at it and so is likely to make a small mistake in its calculations. What are the consequences for the firm? Since the firm's profits are continuous in the decision of the rival, a 'small' mistake leads to a small loss of profits. For this particular example, if the rival produces $(1 + \epsilon)(a - c)/3$ instead of just $(a - c)/3$, the firm's profits fall to $(1 - \epsilon)(a - c)^2/9$, i.e. if the rival's output is 1 percent higher than the Cournot-Nash level, the firm's profits are 1 percent lower than at the Cournot equilibrium.¹⁴

Communication and learning

So far we have considered the harshest test of the rationality assumption by assuming that the firm must make its own output decision in

¹¹ Notice that the notion of 'equilibrium' in game-theoretic models is somewhat different from that used elsewhere (even in other economic applications). Here equilibrium does not mean that, after a long period of adjustment, the system has come to rest. Rather, it simply means that given the strategy that each player is using, no single agent has an incentive to deviate unilaterally from its proposed strategy.

¹² The n th term in the sequence is given by $t_n = [(a - c)/2] - [t_{n-1}/2]$, with $t_0 = 0$.

¹³ Milgrom and Roberts (1990) show that a large class of important games with unique equilibria can be 'solved' in this way.

¹⁴ The loss of profits to the firm is, however, larger than a corresponding mistake by the firm itself. If the firm produces $(1 + \epsilon)(a - c)/3$ by mistake, its profits only fall to $(1 - \epsilon)(a - c)^2/9$. Thus the loss is of second-order importance.

complete ignorance of what its rival will do. In practice the firm will often have some information about its rival's intentions. In particular, there are at least two settings where the firms might feel more confident playing their Cournot-Nash strategies.

The first of these is where the firms have had an opportunity (whether through the media or in person) to discuss their planned actions ahead of time. By this we do not mean that the firms are able to enter into discussions leading up to a binding contractual agreement. Communication of that kind would more likely lead to a collusive agreement than to Cournot behavior. Rather we have in mind that the final output decisions are still made independently.

There is a sense in which such preplay communication (known as 'cheap talk' in the literature) should have no effect on the outcome since the payoffs and strategic options that the firms face aren't altered at all.¹⁵ However, preplay communication can remove each firm's doubts about the reasoning process that the rival is going through. Thus for example, if firm 2 claimed it was going to produce $(a-c)/2$,¹⁶ firm 1 might make the following speech: 'You're only saying that to try to fool me into playing $(a-c)/4$, my best-response to $(a-c)/2$. However, if you believed you had fooled me into doing that you would produce $3(a-c)/8$, your best-response to $(a-c)/4$ and not $(a-c)/2$, so why should I believe you?' The only claim that either firm could make that would not be challenged by the rival would be the claim that the firm intended to produce its Cournot-Nash output! And if both firms have made such claims, each will feel quite confident in going ahead and producing its Cournot-Nash output.^{17,18} Indeed, in this sense, a Nash equilibrium can be viewed as a self-enforcing agreement. If the players have agreed to play their Nash strategies and then go off and independently make their decisions, no individual would have an incentive to deviate from the agreement.

¹⁵ See Farrell (1987) for a discussion of 'cheap talk'.

¹⁶ As we shall see later, firm 2 would like to be able to commit to producing $(a-c)/2$ if that commitment could credibly be communicated to firm 1.

¹⁷ In contrast to how it would feel in the 'rationality' game at the beginning of this section.

¹⁸ Cooper *et al.* (1989) provide some experimental evidence that suggests that 'cheap talk' can in fact make a difference.

Another setting in which a firm might feel more comfortable playing its Cournot-Nash strategy is where it is playing a rival drawn from a pool of firms with experience at the game. With enough experience, the strategies used by the players should not remain biased away from the Cournot-Nash prediction. Suppose, for example, that each firm has developed a strategy that it uses in playing the one-shot Cournot game and that the average of the strategies of the players in the pool is an output of $(a-c)/3+\epsilon$ rather than $(a-c)/3$. If this fact were common knowledge among the players each would soon figure out that it could do better by producing $(a-c)/3-\epsilon/2$, the best-response to $(a-c)/3+\epsilon$. But if they all behaved this way, of course, *this* would become the average production of the pool. This learning process would lead them to $(a-c)/3$, the only 'average' production level that would not induce a change in behavior by a rational opponent.

Some experimental evidence

In experimental settings, the Cournot-Nash predictions are fairly strongly borne out. Moreover, learning of the kind described above does appear to be important in practice. Holt (1985), for example, conducted experiments on undergraduates at Minnesota taking introductory and intermediate economics classes (in which the instructors had not discussed the Cournot game). Twelve students participated in 11 one-shot plays of the Cournot game of which the first was a 'trial run'. Half of the monopoly output (the collusive outcome) was 6 units, the symmetric Cournot-Nash was eight, and if each produced 12 units profits would be zero.¹⁹

Unfortunately, Holt's experiment is not as clean as it might be because with the pay-off structure he used there are also asymmetric Cournot-Nash equilibria: one in which one firm produces six and the other 10, and another in which one produces seven and the other nine. In all cases, however, the predicted total is the same: 16. Another shortcoming is that if one's rival produced its symmetric Cournot-Nash output of eight, the firm would only earn one penny more by producing eight rather than nine.

¹⁹ Forty-five cents was added to all profit numbers to give subjects a reasonable return to their time.

Despite these shortcomings, the results, presented in Table 2 below, are quite striking.

By the final round the outputs were on average very close to the Cournot-Nash levels. After the fifth round all the players except for player 1 (and player 12 in round 10 only) chose to produce either eight or nine units. Notice, however, that almost all of the players started out some distance away from Cournot-Nash, illustrating the role that learning played.

Evaluation of 'literal' models

In this section we have taken a rather literal view of the Cournot model in order to explore the role and limitations of the rationality assumption. What does this exploration suggest about how well we would do predicting behavior in 'real world' settings using a game-theoretic analysis assuming the model accurately captured the setting of interest?

Several general qualitative conclusions seem uncontroversial. First, the burden on the rationality assumption is clearly much higher in some circumstances, such as the 'rationality game' than in others, such as Cournot. This is due in large part to the robustness of the latter to small mistakes by the players. Second, one's confidence in the predictive power of the models is likely to be significantly greater if the players have had the opportunity for preplay communication or, as suggested by the experimental evidence, if they have some experience with the decisions being analyzed.

Despite the rather sanguine view of the ability

of the Cournot game to predict behavior in experimental settings, game-theoretic models have failed the market test abysmally. For example, I know of no instance in which the Cournot model, or even a sophisticated variant of it, has been used in practice by the management of a real world enterprise to guide it in making its output decisions. Moreover, much the same can be said for most of the vast accumulation of models cited with approval in the Introduction. Not only are these models not used in their 'purest' form to predict what rivals 'should' do and hence what one's own best-response should be. They are not even used in modified form to predict what rivals *will* do (even if the firm believes they will not behave as the model says they should) and therefore what the firm should do in that case.²⁰

Perhaps game-theoretic models will become more useful for these purposes over time as the techniques improve. I am skeptical, however.²¹ Game-theoretic models tend to be so complicated that they defy analysis unless they are boiled down to their essence. For example, a model designed to study capacity choices must typically ignore other issues. However, the world does not present itself in such a convenient format. For managers, capacity decisions come bundled with product line decisions, quality decisions, advertising decisions, and so on. The complexity

²⁰ There are some exceptions. For example auction theory has proven useful for competitive bidding.

²¹ For a somewhat contrary view, see Camerer (1991).

Table 2. Outcomes of ten plays of the Cournot Game in an experiment

Subject Period	1	2	3	4	5	6	7	8	9	10	11	12
Trial	7	8	22	10	5	7	13	7	6	8	10	5
1	5	8	9	10	8	6	11	6	9	8	7	7
2	6	8	9	10	8	10	10	7	9	8	7	8
3	6	8	9	9	8	8	10	7	9	8	8	9
4	6	9	9	8	8	8	9	6	9	8	8	9
5	6	9	9	9	9	8	9	8	9	8	8	9
6	7	8	9	9	9	9	8	8	9	8	8	9
7	7	9	9	9	9	9	9	8	9	8	8	9
8	7	9	9	9	9	8	8	8	9	8	8	9
9	7	9	9	9	9	8	8	8	8	8	8	9
10	7	9	9	8	9	8	8	8	8	8	8	10

of those situations easily overwhelms the ability of simple models to cope with them.²²

Overwhelming complexity also typically arises in 'chess-like' situations: those involving long sequences of moves and countermoves where analysis revolves around questions like 'what should firm 1 do if firm 2 does this', how, in turn, should firm 2 respond, and so on? The Kodak–Polaroid and Coke–Pepsi battles, both of which are the subjects of HBS teaching cases, are examples of situations of this type. In the game of chess itself, for example, while game-theory yields the result that there is a solution, it has virtually nothing to say about how one should play the game. And yet chess is a remarkably simple game by comparison with, say, the Polaroid–Kodak battle. At least in chess there is no asymmetric situation, the potential actions are always well-defined, it is clear whose chance it is to move, and, after they have moved, what their move was, and so on.

THE ROLE FOR GAME-THEORETIC MODELING IN STRATEGIC MANAGEMENT: A METAPHORICAL APPROACH

Microeconomic mathematical modeling as metaphor

The rather negative view of the usefulness of game-theoretic modeling in strategic management in the previous section results from attempting to give game-theoretic models a literal interpretation such as mathematical modeling plays in 'management science' (or engineering) applications. While those models are similar in form to models of the microeconomic variety, however, they are quite different in their objectives.

In most models in management science the goal is to provide an *algorithm* which, when data are fed in as inputs, will produce the answer to some management problem (how to schedule

production, how much inventory to hold, etc). When that is achieved, how the algorithm 'works' is of secondary interest.

By contrast, the aim in the kind of microeconomic modeling contemplated here is metaphorical. The model captures and formalizes only selected features of interest; the objective is to create a model which qualitatively simulates a type of environment being studied. Thus there is no attempt to 'calibrate' the model so that it is quantitatively true to a particular setting. Once the formalism is established it is used to derive new qualitative results from the assumptions by a process of deduction. Overall, the model provides well-reasoned arguments by which one can proceed from the assumptions to the conclusions. Understanding why the results obtain, i.e. how the model 'works', is of primary interest. That understanding is what provides the 'insights' which are the final outputs of the endeavor.

The Cournot model provides a good example of the insights that can be gained from metaphorical models. For example, the model demonstrates two important features of noncooperative duopoly behavior: why firms are unable to collude perfectly in a one-period setting, and why they are able to earn higher profits than if there were many symmetric firms in the industry.²³

The model also illustrates why a first-mover advantage might be important. In particular, if firm 1 moves first (the 'Stackelberg' version of this game), it produces more and earns higher profits than in the simultaneous move version.²⁴

²³ If the firms 'agreed' in preplay communication to each produce $(a-c)/4$, half of the monopoly outcome, each would have an incentive to renege on the agreement when it actually came to choosing its production level, since from (2) a firm's best-response to $(a-c)/4$ is $3(a-c)/8$. The same reasoning explains why profits fall as the number of firms in the industry rises. Consider breaking firm 2 into firms 2 and 3. If firm 1 produced its Cournot output of $(a-c)/3$ as before, firms 2 and 3, instead of behaving as a monopolist on the 'piece' of demand remaining for them and producing $(a-c)/3$, they would compete like duopolists and would produce more in total than firm 2 alone would have.

²⁴ Suppose, for example, that we modify the timing of the original game and assume instead that firm 1 gets to produce its output and send it to market before firm 2 does (and that firm 2 observes how much firm 1 has produced before it must make its own output decision). Since firm 2 knows firm 1's output choice when it makes its output decision, its output choice requires no conjecture about what firm 1 'will do'. Its optimization problem is to choose q_2 to maximize $\pi_2 = (a - q_1 - q_2 - c)q_2$, where now q_1 is firm 1's *actual* output. The solution to this problem is that firm 2 produces its best-response to q_1 , i.e. $q_2 = (a - q_1 - c)/2$. For its part,

²² As an exact predictive model of duopoly, Cournot has many shortcomings. The quantity-setting assumption does not mirror most actual settings in which price tends to be the variable that firms compete with, rather than quantities. (Although Kreps and Scheinkman (1983) have shown that in some cases the Cournot model can be interpreted as a two stage model in which the firms first choose capacities and then choose prices.) Moreover, the model lacks the temporal nature of actual competition.

The reason is that firm 1 can credibly commit to a larger output than in the simultaneous move game when it physically makes its production decision before firm 2 does.

The case for mathematical modeling of the microeconomic variety

Despite the potential for 'insight-oriented' mathematical modeling, in strategic management almost all development of theory has been via broad conceptual frameworks, verbally reasoned arguments, or 'models' of the boxes-and-arrows kind. Some of this, such as the conceptual framework captured in Porter's (1980) 5-forces model has been both influential and useful.

However, as Montgomery, Wernerfelt, and Balakrishnan (1989) argue, 'many strategy content publications suffer from serious shortcomings' on the theory development side. Those authors make an appeal for 'well-reasoned theory' but stop short of calling for mathematical modeling. Indeed the examples which they cite with satisfaction do not utilize mathematical modeling but instead proceed by verbal argument.

Of course, mathematical modeling is not *necessary* for careful reasoning and the central arguments in mathematically derived propositions can generally be verbally explained in 'well-reasoned' prose. Moreover, formal modeling is very costly to both authors and readers in terms of the overhead it imposes.

However, formal modeling has three very powerful attributes. The first of these is that it provides an 'audit trail'²⁵ that allows one to distinguish between groundless assertions and logical propositions. By laying out a set of assumptions and deriving the qualitative proposition of interest from them, the author provides the detailed logic that underlies the assertions. There is no ambiguity in such a setting about what it means to be 'well-reasoned' and both the reader and the author can probe the robustness of the results with respect to changes in the assumptions.

Perhaps more importantly, by laying out the

underlying assumptions carefully and explicitly, it is easier for the reader to pinpoint what s/he likes or *dislikes* about the model. If the assumptions are unpalatable so are the propositions which flow from them. And if the proposition is unpalatable or unintuitive, the model provides an audit trail to help point out what unreasonable assumption(s) is responsible. This constant external auditing of the inner workings of the model and its underlying premises provide strong incentives for authors to build their models on solid (and palatable) foundations.

The second important attribute of formal modeling is that it is a methodology that is capable of *creating novel insights*. These insights are often unforeseen and sometimes surprising. They may even seem unintuitive. However, the audit trail that the methodology creates enables one to trace the logic of the argument and reveal whether the 'surprise' is due to an implausible assumption (or assumptions interacting in implausible ways) or to a feature of the 'story' being woven which the author did not realize was there. This virtue of formal modeling stands in contrast to 'models' of the boxes-and-arrows variety which have no built-in capacity for going beyond a mere description of the model itself.

A third major advantage of formal modeling is that it provides a common language that allows related results to be compared, and new results to be built on the foundations laid by earlier models. It thus provides a basis for cumulative learning.

For these reasons modeling has proved very effective in advancing microeconomic theory (including many fields closely related to strategic management) and holds out considerable promise for development of theory in strategic management as well.

Game-theoretic modeling

If one accepts the virtues of mathematical modeling of the microeconomics variety, it does not follow that one should embrace game-theoretic modeling. Yet in strategic management, game-theoretic modeling is likely to constitute a very high fraction of all 'microeconomic style' modeling.

The reason has to do with the nature of the beast. Game-theoretic modeling is the appropriate tool when studying strategic interactions

knowing that firm 2 will respond according to its best-response function, firm 1 choose q_1 to maximize $\pi_1 = [a - (a - q_1 - c)/2 - c]q_1$. This maximization problem has the solution $q_1 = (a - c)/2$.

²⁵ I am grateful to Mark Wolfson for the accountant's terminology.

between agents with differing goals. This, of course, is precisely what characterizes many interesting strategic management issues.²⁶

Two examples illustrate the necessity of strategic thinking in situations where strategic interactions are of the essence. The first, again, is the Cournot model. In order to act sensibly a firm *must* think about what its rival is going to do. Whether or not one accepts the 'solution' to the problem that game theory offers, if one concedes that the duopolists are attempting to maximize profits, one *must* accept the 'strategic thinking' that characterizes game-theoretic analyses.

The second, is a case that is often taught in MBA strategic management classes, *General Electric (GE) vs. Westinghouse in Large Turbine Generators*.²⁷ That case examines the sharp price discounting that plagued the highly concentrated large turbine generator market in the early 1960s. The difficulty that GE had, as the dominant firm, in stabilizing prices could be attributed to a number of market-specific factors.²⁸ The result in a very price sensitive market was that it was difficult for the firms to achieve a 'mutual understanding' as to what prices should prevail and to ascertain whether one's rival had 'cheated' by undercutting those prices. The firms gave in to the unilateral temptation to give discounts off list prices in order to win sales, leading to a steady erosion in prices.

GE's response to this 'problem' was, *inter alia*, to produce a pricing book with simplified pricing

formulas that made it possible to map consumer specifications into list prices, to announce that it would sell to all customers at a specified discount off those list prices, and to commit to a most-favored-customer policy through which any customer who after purchasing from GE learned that GE had later sold similar equipment at a lower price, would be reimbursed the difference.²⁹ This new pricing policy had the effect, within about a year, of ending the deep discounting that had characterized the market previously.

To effectively formulate a new pricing policy GE had to take into account how Westinghouse would respond. They thus had to put themselves in Westinghouse's shoes and predict how Westinghouse would read the signals contained in any change in GE's policy. The policy GE adopted was successful because Westinghouse (ultimately) understood, as GE correctly predicted they would, that the standardized pricing book and commitment to a fixed discount provided an opportunity to coordinate pricing.³⁰ The issues that GE had to consider have to do with the essence of game-theoretic models.

The rationality assumption in metaphorical models

In the previous subsection we stressed the fact that many of the situations of interest in strategic management involve strategic interactions among rivals and therefore require game-theoretic modeling if microeconomic modeling is to be used at all. Just because it is the appropriate tool doesn't mean that one has to like it, however, and those who are skeptical about the degree of rationality required to reach the proffered 'insights' might balk at employing microeconomic modeling at all.

Happily, many of the insights that one obtains from game-theoretic models do not require an extreme degree of rationality. For example, while the implications of the Cournot model do require logical reasoning, the logical reasoning required is far more elementary than the infinite regress

²⁶ A second reason why most microeconomic style modeling in strategic management is likely to be game-theoretic is that game-theoretic modeling has proven to be useful in a very broad class of settings, including many for which game-theory is not essential to the analysis. An example is the well-known signaling model due to Spence (1974). In Spence's original analysis there is a competitive labor market and the analysis is carried out without any of the trappings of game-theory. Now, however, models of what type tend to be framed in the language of game-theory: game theory is emerging as the *lingua franca* of microeconomic modeling. The reason for this is probably related to the appealing audit trail properties of explicitly game theoretic models. As a result, game theory is approaching the status of calculus in the curricula of graduate departments of economics, being required of all students, with courses in elementary game theory often being offered in the first semester of study.

²⁷ The '(A)' part of the case is presented in Porter (1983).

²⁸ These include the fact that, at least for sales to private utilities, sales were made through confidential negotiations and that the product sold was not standard but rather bids were made to satisfy the idiosyncratic specifications set by buyers.

²⁹ The details of GE's pricing policy is discussed in the 'B' part of the case, Harvard Business School, 1-380-129.

³⁰ The logic behind the GE pricing policy was not lost on the Justice Department who concluded that it violated the antitrust laws. (See part (C) of the case).

of the 'If I believe that you believe that I believe . . .' type of reasoning suggests is required. In order to demonstrate that the collusive equilibrium is not sustainable in a one-shot game, for example, all that one has to accept is that either firm will perceive that it can profit by unilaterally deviating. To appreciate that there is a first-mover advantage if one of the firm chooses its output before the other (the Stackelberg game), one simply has to realize that a firm can obtain an advantage by committing itself to a course of action and thereby forcing its rival to respond to a fact of life.

There is a broad class of useful models for which the degree of rationality is not very extreme. These are 'two stage' models where the primary focus is on just one action. Examples of this type include how much capacity a firm facing potential entry should install and how it should price its product, how many products a first-mover should have in its product line, whether firms should make their products compatible or incompatible, how firms should position their products, and so on. In the first stage of these models, the action of primary interest is taken and in the second, the firms compete. The issue of interest is typically how the actions taken in the first stage affect competition in the second.

Often the Cournot model is used as the model of second-stage competition. However, only very broad qualitative features of the Cournot model are drawn upon. Thus, in these models, whether firms would replicate the Cournot outcome in the Cournot setting (the question in the prior section) is virtually irrelevant: only its qualitative features matter.

The explanatory power of metaphorical models

As in the above two examples of entry deterrence, game-theoretic models have the ability to explain a wide variety of observed behavior. Unfortunately, they may be capable of generating too broad an array of predictions. There are two different ways in which this problem arises.

The first is what researchers (somewhat glumly) refer to as the *Fundamental Theorem of Industrial Organization*. This is the assertion that since the assumptions in metaphorical models are selected by the modeler rather than strictly being dictated by a physical setting, and since there is such a rich set of assumptions from which to choose,

the degree of modeling discretion is so significant that a model can be devised to explain almost any fact.

The second way in which the problem of diffuse predictions arises is via multiple equilibria. A wide range of equilibrium behavior may be consistent with the same underlying set of basic assumptions. This is especially true of supergames, which consider infinitely repeated interactions, where multiplicity of equilibria is the focus of the Folk Theorem. We briefly consider each of these issues below.

Multiple equilibria

The issue of multiple equilibria is of some importance since we shall argue below that one of the criteria for choosing among competing models is to consider how their predictions about how a particular variable changes as others change (comparative statics). For example, the Cournot model predicts that if firm 1's costs go up, firm 1's output will fall and by more than firm 2's output will rise. In a model in which there are multiple equilibria, however, such a thought experiment is impossible without also specifying which equilibrium to 'look at' as the variable of interest changes.

Recently game theory itself has been of some help in models with asymmetric information by providing refinements to the Nash equilibrium concept that help the modeler in selecting among equilibria.³¹ In supergames, however, selection among equilibria is often *ad hoc*. For example, sometimes an equilibrium seems particularly 'focal'. At other times, preplay communication would significantly reduce the number of equilibria.

In many of the supergame applications of interest to strategic management, however, the supergame format is selected because it enables consideration of such issues as cooperation and reputation. In such cases, such as where one is attempting to examine the ability of firms to collude over time, one is interested in the extent to which the environment limits the ability of the firms to cooperate. One is then interested in the maximal amount of cooperation that can be sustained without explicit cooperation. It then

³¹ See Kreps (1990b) for details.

makes sense to look at the equilibrium in which the firms do as well as possible. When, in addition, the firms are symmetric or are able to make monetary transfers, this narrows the plethora of possible equilibria to just one and renders the comparative statics exercise sensible.

In other cases, some of the equilibria seem implausible while others are not. In that case the model may be incomplete. Examination of what gives rise to the implausible equilibria may enable the model to be refined by incorporating some important element of the institutions being modeled, eliminating the implausible equilibria and improving the model overall.

In some settings, however, none of the above mechanisms can be called upon to reduce the set of equilibria and one is left with an 'embarrassment of riches'. Yet for some games there just is no obvious way that the game 'should' be played. If game theory were somehow to provide unique predictions in every setting, it would be too powerful for its own good.

The fundamental theorem

The complaint against the 'Fundamental Theorem' is that it is somehow 'too easy' to come up with explanations for phenomena using the tools of game theory. This is a curious complaint. It is the role of theory to come up with explanations. Some of these are likely to be good explanations and others not. And the means for telling them apart is similar whether the theory is generated by game-theoretic modeling vs other means. However, the fact that the explanation has been formally modeled at least ensures that the explanation is internally consistent.

Moreover, modeling provides additional means for telling good explanations apart from bad ones. First, the audit trail makes it easier to assess the argument. Second, and more importantly, in addition to providing the explanation for the phenomenon of interest, the model typically generates a number of other implications, especially of a comparative statics nature. This provides a means to put the model to the test, whether on its surface plausibility or via formal empirical or experimental techniques. If the corollary implications of the model fail to hold then the model must be rejected or at least modified.

RATIONALITY AND PROFIT-MAXIMIZATION

Rationality is sometimes taken to be synonymous with profit-maximization in microeconomic models. Accordingly, to the extent that firms do not seek to maximize profits, this is taken to be a limitation of microeconomic modeling. However, game-theoretic reasoning can be applied even if the objective of the firm, or its management, is not that of profit-maximization. Indeed, a profit-maximizing firm may be better off if its management is not profit-maximizing!

In the discussion of the Cournot model we repeatedly encountered the fact that either firm would value the ability to commit to producing a larger output than it 'rationally' would in the simultaneous move game. We particularly noted the fact that a firm would like to be able to credibly make the speech to its rival that it was committed to producing $(a-c)/2$ (its Stackelberg output).

In such a setting it would be valuable to the firm's shareholders if the manager responsible for the output decision was 'irrational' in that he had a preference for producing more than he would if he were a profit-maximizer. As an example, the manager might want to maximize sales revenue. Supposing that the manager is the decision-maker in firm 1, he would seek to maximize:

$$R = (a - q_1 - q_2)q_1,$$

yielding the best-response function:

$$q_1 = (a - q_2)/2. \quad (3)$$

Comparing (2) and (3) it is evident that the manager behaves more aggressively than his profit-maximizing counterpart. But as discussed previously, having a manager who behaves in this way may be advantageous to the firm because it effectively 'commits' it to higher outputs which in turn induces the rival to curtail its own output. As illustrated in Figure 2, the outcome shifts from B to B' when the manager's goal shifts from profit- to sales-maximization. It is easy to show that firm 1's profits may be higher at B' than at B.

Thus profit-maximizing shareholders might have reason to deliberately select a decision-

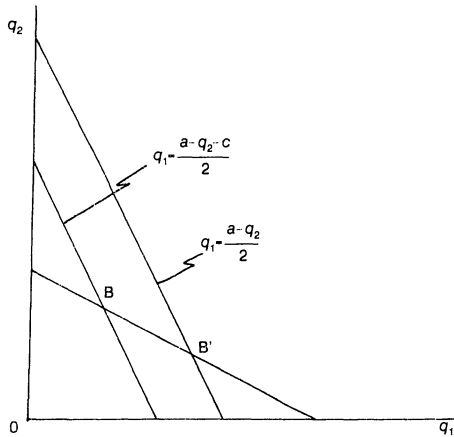


Figure 2. Firm 1 as a sales maximizer

maker who is not profit-maximizing.³² Alternatively, the shareholders might have an incentive to provide the manager with incentives that have the same effect. Thus a firm that can credibly commit to rewarding its manager based on some combination of profits and sales (instead of simply profits) might induce more aggressive behavior in the manager, and consequently, higher profits.³³

Similarly, a firm may have an incentive to install senior management that is not profit-maximizing in order to improve incentives within the organization. As an example, suppose that it is desirable for employees to innovate and that to do this they can exert effort to generate 'proposals' for projects that will enhance profitability. If it is not possible to compensate those workers for the effort that they expend in researching these proposals (because such effort is not observable and hence not contractible) and if the 'quality' of a proposal is too subjective to base compensation on, the only monetary incentive the management can provide is to reward employees when they generate profitable proposals that are in fact implemented.

However, the implementation decision itself is typically in the hands of the senior management. Given the *ex post* compensation that they must

make to the worker if management chooses to implement the proposal, the management will be reluctant to implement proposals that are profitable but where the profits do not cover the additional compensation they must pay the worker. That is, profit-maximizing senior management will be too reluctant to implement projects.

Rotemberg and Saloner (1991) show that this problem can be overcome by installing senior management that cares not only about maximizing profits but also about the welfare of their employees. Such managers will be more likely to implement their employee's projects and hence will earn higher profits than profit-maximizing managers would! In essence, having nonprofit-maximizing management commits the organization to implement the innovative ideas that employees generate rather than to act opportunistically by not implementing them in order to save on incentive compensation.

FROM THEORY TO PRACTICE

The preceding has focused on the role of game-theoretic modeling in producing theoretical insights for strategic management. However, strategic management has historically had very strong normative and empirical orientations. Can game-theoretic modeling contribute in those areas?

Normative role

It was argued above that the prospects are slim for using game-theoretic models as mechanisms for simulating a managerial situation and providing precise prescriptions for managerial action as in a 'management science' type model.

This critique of the direct applicability of game-theoretic models does not mean that they are normatively irrelevant, however. Only by having a good understanding of how its world works can a firm's management understand the repercussions of their own actions and hence how they should behave. The powerful descriptive feature of models and their normative relevance are closely related. The normative role for strategic management here is to provide management with a broad qualitative understanding of the effects of their actions and to ensure that the broad

³² Sales maximizing manager's are not the only one's that might enhance the firm's performance. A manager with a passion for market share or for operating near capacity (provided capacity is not too large) can have similar results.

³³ See Fershtman and Judd (1987) for a model along these lines.

qualitative prescriptions can be given firm foundations.

Empirical role

Significant difficulties arise in directly testing many of the game-theoretic models that have been developed in industrial organization. One reason is that the models tend to be rather specific in that the behavior that emerges in equilibrium depends on the precise state of the environment that obtains. In empirical work it is difficult to find large samples of firms that face exactly the kinds of environments envisaged by the models. A second reason pertains to models with asymmetric information, such as the Milgrom–Roberts (1982a) limit pricing model. The chief implication of that model is that low-cost incumbents will charge less than high-cost ones and thereby successfully deter entry. Unfortunately, the cost structure of the firm must be unobservable to the researcher since if it were observable by the researcher it would be observable by the potential entrant and the model would not apply.

Despite the difficulty that is often encountered in directly testing game-theoretic models, they have had a tremendous impact on empirical research in industrial organization, and hold out similar prospects for strategic management. As Bresnahan and Schmalensee write: ‘The theoretical developments that began in the 1970s produced a rich set of hypotheses, along with a powerful set of modeling techniques . . . (1987: 374)’.

This quote is suggestive of two different roles that game-theoretical modeling plays in empirical work. The first is in developing and refining hypotheses for reduced form empirical models. Here the specific structural characteristics of the models are not used, but instead the empirical investigation examines whether the data are consistent with the broad qualitative features.

As an example, consider the issue of predatory pricing discussed in the previous section. The models discussed there suggest that a firm that has developed a reputation for predatory behavior should find it easier to drive rivals out than firms with no such reputation. Furthermore, Saloner (1987), shows that a firm may have an incentive to predatory price against a rival in anticipation of a merger with that rival to enable it to

purchase the rival on better terms. Both of these qualitative features are examined in Burns’ (1986) empirical investigation of the acquisitions by the American Tobacco Company. He finds that ‘alleged predation significantly lowered the acquisition costs of the tobacco trust both for asserted victims and, through reputation effects, for competitors that sold out peacefully’ (p. 286). Moreover, the effects were significant in magnitude: ‘The estimated direct savings range up to 60 percent of what some targets would have cost if they had not been preyed on, and the trust’s reputation produced an additional discount averaging 25 percent’ (p. 289).

In addition to directly examining the central qualitative predictions of models as in these examples, as discussed above, hypotheses are often generated from the comparative statics of the model. For example, in a supergame-theoretic model Rotemberg and Saloner (1986) show that an implicitly colluding oligopoly might find it most difficult to collude when demand is at its strongest because the incentive for a firm to cheat is greatest then. A corollary of that analysis is that price-cost margins should be lower for such firms when demand is high, so that measured price-cost margins should be countercyclical. Empirical evidence, much of it supportive of this hypothesis, has been produced by Rotemberg and Saloner (1986), Domowitz, Hubbard and Petersen (1987), and Rotemberg and Woodford (1989, 1991).

The second role that game-theoretic modeling plays in empirical work is in generating and testing structural models. These empirical investigations focus on a particular industry over time. Typically demand, costs, and behavior are estimated simultaneously, and the relationships between the various parameters to be estimated are dictated by oligopoly theory. While detailed game-theoretic models underlie these structural models, the estimation relies on the broad qualitative features, especially the relationships among the degree of collusion, price-cost margins, and demand elasticities, that hold at equilibrium, and the comparative static properties of those relationships.

Two of the best examples of this style of work are the papers by Porter (1983) and Bresnahan (1987). Porter (1983) uses a switching regression model to estimate periods of cooperation and reversion in the railroad cartel of the 1880s. The

pattern of behavior estimated by the model is consistent with that predicted by the Green and Porter (1984) model and the estimated price–cost margins during periods of collusion are consistent with the exercise of considerable market power. Bresnahan (1987) uses a model of product differentiation to estimate the degree of collusion among US auto manufacturers from 1954 to 1956. He finds that the years 1954 and 1956 were collusive while 1955 was competitive. His structural estimation allows him to estimate price–cost margins during periods of collusion and competition for different car models.

There has been a tendency among some observers to stress some of the difficulties in directly testing some game-theoretic models. However, the renaissance in empirical work that has followed the theoretical developments has been remarkable and while the pace of development of theory within industrial organization seems to be slowing, ‘the new empirical industrial organization’ continues apace.³⁴

CONCLUSIONS

When small numbers of rival compete, a sensible analysis of what a firm should do involves a careful assessment of what its rivals’ actions are likely to be. A formal analysis of such situations therefore requires assumptions about how rivals behave. Game theory proceeds, for the most part, by assuming that all the rivals behave rationally.

We have argued that in order to evaluate game-theoretic modeling it is important to consider the goals of the analysis. We have argued that one’s appraisal of the rationality assumption and of the usefulness of the models depends on whether one takes a literal or metaphorical view of microeconomic style modeling.

Taking the literal view, comparing the role of the rationality assumption in the Cournot game and in the rationality game considered in the introduction leads to quite different impressions. The degree of rationality assumed in the latter is clearly much greater than in the former. Reasonable people might reach different conclusions about whether the degree of rationality

assumed in each is within the realm of plausibility. That judgement must, however, be made on a case-by-case basis. Thus one might well be willing to accept the conclusions of game-theoretic reasoning in some settings and not in others.

We have argued that one ought to be relatively more comfortable with the predictions of game-theoretic analyses in literal models, all else equal, when the prediction is robust to small mistakes by the players, when the players have some experience with the decisions being analyzed, or when the players have some basis on which to form beliefs about what their rivals will do (whether because there has been preplay communication, or because they have had opportunities to observe each others’ behavior in the past).

However, we have argued that there is likely to be a limited role for literal game-theoretic models. In particular, game-theoretic models have not proven very useful, nor are they likely to, for providing *precise* prescriptions for managerial behavior. Rather, the role of game-theoretic modeling is to produce insights from well-reasoned models. That is, the virtues of game-theoretic modeling have as much to do with the virtues of modeling as with the virtues of the game-theoretic approach.

These virtues of formal modeling are, *inter alia*, that it provides an ‘audit trail’ that documents that a coherent explanation for the phenomenon under study can be given; it provides a system of logic to root out the flaw in the reasoning in incorrect analyses (as in the case of the maintained output hypothesis); that it is a methodology capable of generating new insights (including ‘surprises’), and that it provides a common language which allows related results to be compared, and new results to be built on the foundations laid by earlier models.

What does the field have to look forward to if there is indeed a large increase in the ‘domestic’ production of game-theoretic modeling in strategic management? If experience in industrial organization is any indicator, the cumulative output is likely to be more in the way of a mosaic with many papers each contributing a small piece of the puzzle than in the way of broad generalizing theory. That is, results are more in the way of describing what happens in particular circumstances rather than on describing behavior that will occur in all, or even in a very broad variety, of situations. As theory develops, more and more

³⁴ See Bresnahan (1989) for a detailed discussion of the ‘new empirical Industrial Organization’.

is learned about the limits of particular models and the circumstances under which their results hold. Pieces of the mosaic are replaced by others, and empty spots are filled in. Some, such as Fisher (1989) lament the scale of the mosaic. However, the large scale is due to the enormous variability of the settings and decisions that senior management most confront. The enormous scope of those settings requires richly textured theory.

It is the task of the scholars in the field to develop and maintain this richly textured mosaic, to contribute the pieces to it, and to haggle over which ones belong and how they fit. While it is time-consuming, this approach is also cumulative. Rather than haphazardly generating a myriad of disconnected and conflicting theories, each starting from scratch, in this approach each contribution builds upon those of its predecessors. This task is both theoretical and empirical. Theory provides both hypotheses to test and specific structural models in which to test them. Empirical results, in turn, provide evidence on the limits, applicability, and failures of the theory, pointing to deficiencies in the mosaic and presenting new challenges to theory.

As it develops, each part of the mosaic provides understanding of some aspect of the business environment which, in turn, enables managers to make sensible decisions. Thus, while not narrowly prescriptive, as in literal models, metaphorical models nonetheless are normatively useful.

The program being called for in this paper is not the continued development of game-theoretic modeling in industrial organization for export to strategic management. Rather it is the development, within strategic management, of its own mosaic: the rigorous development of theory on topics central to strategic management by scholars in strategic management.

As far as subject matter is concerned, there are topics to be addressed in both the internal and external parts of strategic management. On the external side, for example, a topic that has received a huge amount of attention in the strategy literature but little formal modeling is the issue of strategic groups (see Porter, 1980).

On the internal side, many issues are related to the growing body of work in 'contract theory'. In particular, questions relating to the appropriate boundaries of the firm which are central to strategic management may be amenable to

analysis using these tools. These include the study of joint ventures and strategic alliances as well as issues relating to the scope of the firm. The latter includes optimal diversification policy as well as questions such as why firms often set narrow strategic objectives for themselves (see Mintzberg, 1987).

A related set of issues are raised by the resource-based view of the firm (Penrose, 1959; Wernerfelt 1984). Which resources and core competencies are worth developing depends, in part, on the extent to which the firm is able to capture the rents from them. It also depends on the firm's ability to commit itself to adequately rewarding those individuals in the firm who must put forth the effort to develop those resources and competencies. How the implicit and explicit contractual relationships that the firm can enter into with its employees and the nature of rent-sharing within the firm influence the development of the resource base of the firm are important topics that may be amenable to contract-theoretic modeling.

In the final analysis, the proof of the pudding is in the eating. Only by applying game-theoretic modeling to issues in strategic management will we be able to assess its usefulness to the field. Hopefully the next time a conference of this nature is convened the debate over the virtues of game-theoretic modeling in strategic management will be concrete rather than merely philosophical.

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