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Can game theory be saved?

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Abstract

Game-theoretic analysis is a well-established part of the toolkit of economic analysis. In crucial respects, however, game theory has failed to deliver on its original promise of generating sharp predictions of behavior in situations where neoclassical microeconomics has little to say. Experience has shown that in most situations, it is possible to tell a game-theoretic story to fit almost any possible outcome. We argue that, in general, any individually rational outcome of an economic interaction may be supported as the Nash equilibrium of an appropriately chosen game, and that a wide range of these outcomes will have an economically reasonable interpretation. We consider possible attempts to salvage the original objectives of the game-theoretic research program. In at least some cases, information on institutional structures and observations of interactions between agents can be used to limit the set of strategies that may be considered reasonable.

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1 Introduction

On the face of it, game theory is in no need of saving. Game-theoretic analysis is a well-established part of the toolkit of economic analysis, with several Nobel prizes to account for its significance. Game-theoretic concepts, most notably Nash equilibrium, are routinely employed in all areas of economics. Mostly confined to graduate courses as recently as the 1980s, game theory is now a standard part of the undergraduate curriculum.

In crucial respects, however, game theory has failed to deliver on its original promise of generating sharp predictions of behavior in situations where neoclassical microeconomics has little to say. In particular, it was expected that game theory could be used to model markets that fitted neither of the polar categories of monopoly and perfect competition, the only kinds for which standard microeconomics yields a clear solution. The work of pioneers such as Cournot, Bertrand and Stackelberg, reinterpreted in terms of Nash equilibria, appeared to indicate the direction in which progress could be made.

These expectations now appear over-optimistic. Experience has shown that in most situations, it is possible to tell a game-theoretic story to fit almost any possible outcome. Although this point is only occasionally acknowledged in the formal literature, it is much more widely accepted in informal discussion.

Mandel (2005) says:

> *Game theory represents an evolutionary dead-end in the development of economics. Game theory tries to use the principle of rationality to explain conflict and cooperation in a wide range of economic and social situations. For example, game theory has been used to analyze why the apparently insane buildup of nuclear weapons in the postwar period was actually a rational method of deterring war, and why aggressive price-cutting by airlines was an effective means of deterring competition.*
>
> *Game theory is no doubt wonderful for telling stories. However, it flunks the main test of any scientific theory: The ability to make empirically testable predictions. In most real-life situations, many different outcomes – from full cooperation to near-disastrous conflict – are consistent with the game-theory version of rationality.*
>
> *To put it a different way: If the world had been blown up during the Cuban Missile Crisis of 1962, game theorists could have explained that as an unfortunate outcome – but one that was just as rational as what actually happened. Similarly, an industry that collapses into run-amok competition, like the airlines, can be explained rationally by game theorists as easily as one where*

cooperation is the norm.

In this paper, we show that Mandel's assessment is supported by a number of well-established propositions. The best known of these is the folk theorem on infinitely-repeated games. However, the Klemperer-Meyer analysis of oligopoly, showing that any outcome with non-negative profits for all firms can be derived as the Nash equilibrium of a game with supply shcedules as strategies is probably the most important. We argue that this and related results can be extended to a wide variety of economic interactions commonly modelled in game theoretic terms, and illustrate this point with a consideration of Tullock contests, which we argue can be represented in terms of markets for influence. Hence, it can be shown that equilibria analogous to Cournot, Bertrand and a continuum of intermediate cases may be supported for Tullock contests of all kinds, regardless of the success function, which has been the main focus of analytical attention in the Tullock contests literature. We show that the same point applies to a large generic class of economic interactions.

Thus we claim to have shown that, in general, any individually rational outcome of an economic interaction may be supported as the Nash equilibrium of an appropriately chosen game, and that a wide range of these outcomes will have an economically reasonable interpretation. We consider arguments to the effect that this is not a serious problem for game theory as it is currently practiced, and conclude that such arguments cannot be sustained.

Next, we consider possible attempts to salvage the original objectives of the game-theoretic research program. We argue that, in at least some cases, information on institutional structures and observations of interactions between agents can be used to limit the set of strategies that may be considered reasonable. This empirical evidence may be integrated with axiomatic characterisation of reasonable choices of the strategy space.

2 Background

In the postwar development of game theory, the crucial turning point was the discovery of the folk theorem, which, in its various forms, states that any individually rational outcome of a game may be derived as the Nash equilibrium of an infinitely repeated game. The central idea, to which we will return, is that any one player can enforce the acceptance of their preferred equilibrium by adopting a 'Grim' strategy of permanent non-cooperation if anyone else deviates.

The bitter pill was sweetened by the observation that, in some cases, 'unbelievable' equilibria could be ruled out by the imposition of additional criteria such as subgame perfectness. This gave rise to a more general research program based on the search for 'refinements' of Nash equilibrium that would, ideally, generate unique equilibrium predictions for indefinitely repeated games.

By the end of the 1980s, the refinements literature had reached a dead end. As Alexander (2003) observes

> *Unfortunately, so many refinements of the notion of a Nash equilibrium have been developed that, in many games which have multiple Nash equilibria, each equilibrium could be justified by some refinement present in the literature. The problem has thus shifted from choosing among multiple Nash equilibria to choosing among the various refinements*

While the folk theorem implied a significant narrowing of the theoretical scope of game theory, it did not directly challenge the validity of the main economic applications of game theory, most of which related to one-shot or finitely repeated games. Developments in the theory of oligopoly are arguably more significant, though they have attracted less attention.

The crucial result is that of Klemperer and Meyer (1989) who show that, if arbitrary supply schedules are allowed as strategies, any market outcome consistent with individual rationality (non-negative profits) can be supported as a Nash equilibrium. This result can be illustrated by numerous choices of strategic representations, at least as plausible as the standard Cournot and Bertrand representation. For example, Grant and Quiggin (1996) analyse the cases when the strategic variables are fixed or ad valorem markups. Menezes and Quiggin (to come) analyse the case of revenue as a strategic variable.

As with the folk theorem, the negative Klemperer–Meyer result was accompanied by a hopeful positive direction. KM proposed a new equilibrium concept based on the premise that uncertainty in the demand function could constrain choices in such a way as to yield a unique equilibrium. This idea has been applied to British electricity markets (See, for example, Green and Newbery, 1992, 1996), but has not been adopted more generally.

Menezes and Quiggin (2006) extend the KM argument to economic interactions in general. The central result is that for any individually rational outcome of an economic interaction, any game-theoretic representation of that economic interaction can be extended, by the inclusion of additional strategies, to support the given outcome as a Nash equilibrium.

3 A critique of current practice

The theoretical analysis described in the previous section demonstrates that, in the absence of additional structure, game theoretic representations of economic interactions, whether one-shot, finitely repeated or infinitely repeated, cannot rule out any individually rational outcomes. To understand this negative result, and to consider possible ways forward, it may be useful to consider a more specific critique of current practice.

We begin by considering a general class of economic interactions which may be represented in game-theoretic terms. We show that representations of such interactions may take a form which leads to a seemingly natural specification of the associated game, but that in fact

We illustrate this point by considering two areas to which game theory has been applied: duopoly and oligopoly problems in industrial organization and contests modelled using the approach developed by Tullock.

We show that the two problems are isomorphic in a formal sense and that this isomorphism has a natural economic interpretation. Nevertheless, because the standard representations differ, the strategy spaces assumed to be available to players, and hence the set of Nash equilibrium outcomes, also differ.

3.1 Economic interactions

Consider an economic interaction involving N agents. The outcome of the interaction may be derived from an equation of the form

$$y = f(x_1, ...x_N)$$

where x_n is a variable (discrete, continuous or mixed) summarising the action of agent n. Each player's return is given by

$$u_n = u(y, x_n)$$

Among the many examples that may be described in this way are oligopoly problems, Tullock contests and contributions to public goods. More generally, Hartley and Cornes (2006) define the category of aggregative games, all of which admit representations of this kind.

At this point, the standard procedure would be to treat the information above as the basis for a game-theoretic representation with the strategy space for player n given by x_n, and solve using the Nash equilibrium or some related equilibrium concept. To pick just one example, the presentation of the general Tullock problem in the excellent survey by Konrad (2004) takes exactly this approach.

But there is a crucial gap in the argument. Nothing thus far warrants the assumption that the strategy space for the given interaction is given by X_N. On the contrary, it is easy to show that the same interaction may be represented in arbitarily many different ways, each of which has an equal prima facie claim to define the strategy space.

Consider any strictly monotone transformation $z_n = z(x_n, y)$. We can easily show that there is a 1-1 mapping from X to Z and an outcome representation $g(z, y)$ that is identical in form to that given above, and conveys exactly the same information.

As a means of representing the determination of outcomes, any two representations of this kind are equivalent, and the choice between them may be determined by the preferences and analytical background of the modeler. For example, economists are used to representing market situations in terms of supply and demand curves, so the Cournot representation of oligopoly, with quantity as the firm's action variable, and market price determined by the demand curve, seems entirely natural.

However, there is no reason to suppose that a representation that is analytically convenient for economists will be a sensible choice of strategic variable for a game-theoretic representation. As Grant and Quiggin observe, for example, quantities and prices vary over time and are in any case not well-defined when (as is nearly always the case) output is heterogeneous. By contrast, a firm may, if it chooses, hold markups constant over arbitrarily long periods. Hence, it may be suggested, markups are a more plausible choice of strategic variable than either prices or quantities.

3.2 An example: Elections as duopoly games

Consider a two-person standard Tullock contest that can be thought, as it has often been the case in this literature, as an election. The usual strategic representation has each of the candidates choosing the total amount to be spent in the campaign. In this context, if we denote candidate i's choice by c_i, the probability that i wins the election is simply given by:

$$\pi_i = \frac{c_i}{c_i + c_j}.$$

The utility or payoff of player i is is then given by:

$$V_i = \pi_i - c_i,$$

with the normalisation of the 'prize' for winning the election to one. This strategic representation of the elections game has a unique equilibrium in pure strategies which is symmetric and where both agents choose

$$c_1 = c_2 = \frac{1}{4}.$$

To explore the connection with oligopoly games, we now consider the case where there is a linear supply of electoral influence which is given by:

$$p = q_1 + q_2,$$

with the interpretation that p is the price paid by the candidates for each unit of influence and q_i the influence gained by candidate i. Accordingly,

$$c_i = pq_i, i = 1, 2.$$

As before, we assume the success probabilities are given by

$$\pi_i = \frac{c_i}{c_i + c_j}. = \frac{q_i}{q_i + q_j}$$

Now consider the 'Cournot' strategic representation where the candidates choose quantity q_i to maximise:

$$V_i = \frac{pq_i}{p(q_i + q_j)} - pq_i.$$

This representation has a unique symmetric equilibrium where

$$q_1^C = q_2^C = \frac{1}{2\sqrt{3}},$$

and consequently

$$p^C = \frac{1}{\sqrt{3}}$$

and

$$c_1^C = c_2^C = \frac{1}{6}.$$

Now consider a strategic representation that is equivalent to a 'Bertrand' model of oligopoly. Under this scenario the candidates compete for voters in the 'prices 'space. We impose the standard assumptions in Bertrand competition, where the voters will vote for the candidate who offers the higher price. In the event that both candidates offer the same price, voters are equally split among the two candidates. It is not difficult to see that the Bertrand (auction) logic implies that in equilibrum:

$$p_1^B = p_2^B = 1.$$

That is, any price lower than one leads to 'undercutting'. Under this equlibrium, there is zero profits and full rent dissipation as

$$q_1^B = q_2^B = \frac{1}{2} = c_1^B = c_2^B.$$

The same approach can be used to derive equilibria in fixed and ad valorem markups over unit cost, as in Grant and Quiggin. More generally, the Klemperer-Meyer proof that any individually rational outcome may be supported as an equilibrium in supply schedules can be adapted to the present case.

3.3 Asymmetric equilibria

Thus far, we have focused on symmetric equilibria. Observation of, for example, elections, suggests that asymmetric equilibria are of equal interest in the analysis of Tullock contests.

One strong prediction of the standard Tullock contest model is that there are no Nash equilibria in which only one player contributes, winning with probability 1. The argument is reasonably straightforward. Consider a candidate equilibrium in which $p_1 > 0, p_j = 0$ for $\dot{j} \neq 1$. Then player 1 can benefit by reducing her contribution. Also, if p_1 is small enough, other players can benefit by contributing. More formally, $\frac{\partial u_1}{\partial p_1} = -1$ at $p_2 = p_3 = ... = p_n = 0$. Similarly, Player 2's best response when $p_1 > 0$ and $p_3 = ... = p_n = 0$ is such that $\frac{\partial u_2}{\partial p_2} = \frac{1}{p_1} - 1 > 0$ at $p_2 = 0$. Thus, Player 2's best reply to $p_1 > 0$ and $p_3 = ... = p_n = 0$ involves a positive effort or contribution.

Indeed, in this game, the unique (symmetric) Nash equilibrium is such that $p_i = \frac{n-1}{2n} = p$ for $i = 1, ..., n$. To see this, note that $\frac{n-1}{2n}$ is the solution to $\frac{\partial u_1}{\partial p_1} |_{p_2=p_3=...=p_n}= \frac{1}{p_1+(n-1)p} - \frac{p_1}{(p_1+(n-1)p)^2} - 1 = 0$.

That is, under a strategy space where players choose a contribution level p_i, the prediction is that all players will make positive and identical contributions. In reality, though, uncontested elections are common. Indeed, we show next that it is possible to obtain this as an equilibrium outcome of asymmetrical games with different specifications of the strategy space, in which the uncontested winner is the first mover.

We model this assymmetric game by assuming that player 1's strategy space is given by a probability of winning $\pi^*{}_1$,$0 < \pi_1^* < 1$, with the special interpretation of a minimal contribution δ_1 if all other players choose 0, in which case player 1 receives the prize with probability 1. For $\dot{j} \neq 1$, the strategy spaces consist of contribution levels p_j, as before, and again we avoid continuity problems by requiring that either $p_j = 0$ or $p_j > \delta_j$ for some $\delta_j > 0$.

That is, having chosen π_1^*, and conditional on the (non-zero) strategies p_j of the other players, player 1 is required to contribute p_1^* such that

$$\pi_1^* = \frac{p_1^*}{\sum_j p_j} \quad .$$

As an example, consider the case where $n = 2$, and suppose the contest involves expenditure on professional pollsters, campaign consultants and so on. There is a pool of service providers available, and player 1 chooses to retain the services of some subset of the providers, leaving the rest to player 2. Player 2 chooses whether to run , and if so, how many days of campaigning will take place. Player 1 pays for his retained providers for the length of the campaign, or pays δ_1 if 2 does not run. Then π_1^* is simply the proportion of the pool of service providers (expressed in terms of cost per day of campaigning) retained by 1.

More generally, following Baik and Shogren (1992), we can suppose that Player 1 commits to match some proportion π_1^* of the contributions of the other players. In an election context, it is natural to think of Player 1 as the incumbent. However, much the same analysis could apply to an open seat in which one candidate is seen by the others as having the capacity to match as much of their spending as (s)he chooses.

The symmetric Nash equilibrium of the standard Tullock game is also a Nash equilibrium of the new game. However, there is also an additional family of Nash equilibria where player 1 makes the minimal contribution δ and receives the prize with probability 1.

To check this, note that if player 1 chooses π_1^* consistent with a contribution $p_1 = \frac{n-1}{2n}$, it is a best reply for players $2, ..., n$ to contribute $p = \frac{n-1}{2n}$. Similarly, when players $2, ..., n$ contribute $p = \frac{n-1}{2n}$, player 1's best reply is to choose $\pi_1^* = \frac{1}{n}$, which is consistent with a contribution of $p_1 = \frac{n-1}{2n}$. To see that there is an additional family of Nash equilibria where player 1 makes the minimal contribution δ and receives the prize with probability 1, observe that, if $\pi_1 > 1 - \frac{1}{\delta_j}, \forall j \neq 1$, the best-reply strategy for player j is $p_j = 0, \forall j \neq 1$. Conversely, given that all $p_j = 0, \forall j \neq 1$, the choice of π_1 is weakly optimal, since player 1 pays δ_1 and receives the prize regardless of the choice of π_1. Since player 1 moves first, this is subgame perfect. (The family of such equilibria corresponds to values of π_1^* in the interval $max_j \left\{1 - \frac{1}{\delta_j}, 1\right\}$, but the outcome is the same in each case).

3.4 Generalizations

The example given above can be generalized to Tullock contests of all kinds, and will typically give rise to natural economic interpretations of variables analogous to the price and quantity of electoral attention, the Cournot, Bertrand and markup strategies and so on. Note that the choice of strategic representations is orthogonal to the variation more commonly considered in the literature on Tullock contests, the success probability function mapping a vector of efforts to a vector of success pobabilities.

Thus, any outcome from complete dissipation of rent to the substantial duopoly profit associated with the quasi-Cournot outcome can be given a plausible interpretation, and any individually rational outcome can be represented as a Nash equilibrium in supply schedules. As illustrated above, this includes asymmetric outcomes

More generally, in any social interaction where economic modelling is relevant, there must be some analog to a market, with associated prices and quantities. Just as with Tullock contests, game-theoretic representations are available yielding equilibrium solutions analogous to Cournot, Bertrand, fixed and variable markups and so on.

Finally, the results of Menezes and Quiggin (2006) extend the general folk theorem resulting to one-shot and finitely repeated economic interactions.

4 Does it matter?

Taken cumulatively, the folk theorem, the Klemperer-Meyer analysis of oligopoly and the more general analysis of economic interactions presented here demonstrate that, given a description of an economic interaction and a feasible outcome consistent with individual rationality, a strategy space can be chosen for which the given outcome is a Nash equilibrium (under fairly weak conditions, the unique Nash equilibrium). Any symmetric outcome for a typical aggregative game can be represented as an Nash equilibrium for strategies defined by some strategic variable that may be interpreted as a function of price and quantity, and there is in general, no warrant for preferring any particular choice of strategic variable.

Nevertheless, it may be argued, current practice does not to change, or at least does not to change significantly, in response to this observation. We first consider methodological defences based on the claim that a requirement for specific predictions is inappropriate. Next we consider the claim that the choice of strategy space is not, in fact, problematic, but is undertaken appropriately in standard applications of game theory to economic problemes.

4.1 Methodological defences

One way of viewing this finding is as an explanation of the extraordinary market success of the game-theoretic program. Whatever the observed outcome, a game-theoretic explanation is guaranteed to exist, and it is up to the ingenuity of the theorist to find the appropriate strategy space and put forward a plausible *ex post* rationale. In this sense, the success of game theory is similar to the earlier successes of Freudian psychoanalysis and Marxist analysis of political and economic phenomena.

The critique of such theories by Popper, who presented falsifiability as a demarcation criterion separating scientific from nonscientific reasoning, and pointed to Freudianism and Marxism as prime examples of non-falsifiable theories has been generally accepted by economists. However, a storytelling approach has been defended, most notably by McCloskey.

Responding to Mandel (2005) Cowan (2005) suggests the possibility that

> *The real world is in fact indeterminate or close to indeterminate. The indeterminacy and multiple equilibria of game theory are not a problem, but rather reflect how closely the theory mirrors reality. Yes you might prefer sharp, clear predictions, but tough tiddlywinks, you're not going to get them. Faithfulness to reality is more important than fulfilling abstract methodological strictures.*

and says that, if this is true, game theorists could ' *declare victory and* *go home.'* Cowan further observes that 'Like so much of economics, the strongest argument for game theory is simply to chat with someone who doesn't know any' which (in the absence of a claim for predictive power) is most naturally interpreted in terms of the rhetorical or storytelling approach favored by McCloskey.

Despite the appeal of the rhetorical approach as a description of much actual practice, it does not appear satisfactory except to define a linguistic community. In the absence of predictive power, it is unclear why game-theoretic descriptions of, say oligopolistic markets, should be preferred to, say, Marxist accounts of the same phenomena, or the personality-based analyses that characterise much of the business press.

4.2 A misrepresentation of current practice?

In the discussion above, it was argued that given an outcome representation of the form $y = f(x_1, ...x_N)$ it is inappropriate to assume that the situation can be modelled as a game in which the strategy space for player n consists of possible choices of x_n. It might be objected that this is not an accurate representation of game-theoretic practice, and that the choice of strategic representation is normally based on explicit consideration of substantive economic considerations rather than being read off from an essentially arbitrary choice of representation.

We do not accept this objection, at least as a general description of current practice.Standard texts on game theory pay little or no attention to the determination of the strategy space. Rather they typically rely on examples in which the strategy space is fixed by assumption and focus on the determination of equilibrium outcomes.

Our assessment is supported surveys of particular fields such as Konrad's excellent summary of the literature on Tullock contests. Although a wide range of issues is discussed, the choice of strategy space is barely mentioned. The closest approach is the work of Baik and Shogren, discussed above.

Even in the absence of formal attention to the question, we do not claim that all applications of game theory follow a purely mechanistic approach. Skilled practitioners of game theory may well initial representations that give rise to reasonable representations of the strategic interaction, even if they do not make this explicit. But this makes economic application of game theory an art rather than a science. And in the absence of a detailed knowledge of the problem at hand, it is difficult for a reader to determine whether a given application is the product of skilled handling of game-theoretic tools or merely a mechanistic application of textbook techniques (technical skill in the derivation of equilibrium is likely to be orthogonal to understanding of the economic situation being modelled).

5 Can game theory be saved ?

5.1 Improved modelling of individual behavior

In a response to Mandel entitled , Cowen (2005) implicitly concedes Mandel's claim about the current state of game theory and says:

> *I can think of possible responses:*
>
> *1. Behavioral approaches will flesh out how humans actually behave. Game theory will end up with clear predictions, just give it time.*
>
> *2. Computational approaches will flesh out how humans actually behave. Game theory will end up with clear predictions, just give it time.*
>
> *3. Evolutionary approaches will flesh out how humans actually behave. Game theory will end up with clear predictions, just give it time.*
>
> *4. Experimental approaches will flesh out how humans actually behave. Game theory will end up with clear predictions, just give it time.*
>
> *Any one of these answers would suffice and allow us to push full steam ahead*

These claims can be interpreted in various ways. From the viewpoint of the literature arising from the folk theorem, and particularly the discussion of refinements the most natural interpretation is that studies of individuals from the various approaches listed above will make it possible to identify Nash equilibria in a given game that are consistent with actual human behavior and to discard those that are not.

This approach fails to take account of the interpersonal nature of the interactions dealt with by game theory, and the way in which those interactions are represented by the Nash equilibrium concept. A Nash equilibrium is an outcome where each player believes themselves to have chosen the best available strategy, contingent on the assumption that the other player is pursuing a particular strategy. Given the availability of alternative strategic representations, what matters is not the players' subjective representations of their own strategies but the strategy that each player imputes to the other.

This point may be illustrated by considering a duopoly interaction in which each player represents as a game in which the player concerned adopts a Bertrand (price) strategy, while assuming that the other player adopts a Cournot (quantity) strategy. Let the market demand be $D(p)$, and let the inverse demand function be $P(Q)$ Consider the best response price choice for player i conditional on the quantity choice for j. The best response function is given by

$$p_i^* (q_j) = \arg\max_{p_i} p_i (D(p_i) - q_j) - C_i (D(p_i) - q_j)$$

Observe that

$$p_i^* (q_j) = P(q_j + q_i^* (q_j))$$

where

$$q_i^* (q_j) = \arg\max_{q_i} q_i P(q_j + q) - C_i (q_i)$$

5.2 Alternatives to Nash equilibrium

The analysis above has focused on the Nash equilibrium concept, and its refinements. It may be that alternative equilibrium concepts will prove robust to criticisms of the kind put forward here. Most obviously, the validity of the maximin solution for zero-sum games is not called into question by the analysis above. In fact, it is the ability of any player to achieve their own maximin outcome in any game, zero-sum or otherwise, that bounds the set of feasible Nash equilibria. However, since most economic interactions are not zero-sum, the maximin solution concept is only rarely of interest except as a source of bounds.

Some more promising possibilities may be found in evolutionary game theory. Perhaps consideration of conditions under which strategies will survive in a population, given evolution over time, may yield more robust characterisations of the set of equilibria than those considered here.

5.3 Choosing the strategy space

If all individually rational economic outcomes can be modelled as Nash equilibria for given strategy spaces, the determination of the strategy space is obviously of central importance.So, it is natural to consider ways in which economic agents might seek a favorable determination of the strategy space.

One approach explored in the oligopoly literature is that of a two-stage game, where the choice made in the first stage constrains the strategies adopted in the second stage. For example, Kreps and Scheinkman consider a two stage game with capacity chosen in the first stage, and Bertrand competition in the second. They derive Cournot equilibrium as the unique subgame perfect equilibrium. However, Grant and Quiggin (1996) show that with Cobb-Douglas technology and the solution concept of Klemperer and Meyer, any outcome from Cournot to Bertrand can be sustained in this way.

The issue of how to analyse a strategic situation when the rules are not properly specified has been also studied by Agastya (2005). He shows for example that, under some circumstances, the familiar utility theory tools can be applied to modeling how individuals make choices among strategic situations when the rules of play are not precise. This seems to be a promising avenue to pursue in circumstances where the consequences of various individuals' choices or actions are known such as when there is a set of players, a pie of a given size that players can share if they agree on how to do it. In such circumstances, although the particular 'rules' of the bargain are not known, Agastya shows that it might be possible to sensibly define choice rules that can be interpreted as the 'rules of the game'. The difficulty of course is that such approach might be difficult to apply to situations where the 'size of the pie' changes with different individual choices.

A more general question is whether the determination of the strategy space should be interpreted as the first stage in a multi-stage game. The difficulty with this approach is that the general results of Menezes and Quiggin (2006) showing that any individually rational equilibrium outcome can be supported as a Nash equilibrium of an extended game are applicable to two-stage games of this kind, considered in normal form. Hence, it seems likely that game theoretic reasoning must be supplemented with additional economic or behavioral information if sharp predictions are to be obtained about the determination of the strategy space.

5.4 More attention to institutional structure

The analysis above has shown that no useful statements about equilibrium can be derived simply from a specification of the outcome space as a Cartesian product of summary statistics for the actions of individual agents. This issue did not arise in early applications of game theory, since analysis was applied to games such as chess and poker. In these games the rules specifying the permissible strategies are either written (as in chess and standard versions of poker), or agreed by custom (as in nonstandard versions of poker). Leaving aside the possibility of cheating, the epistemic status of the strategy space is not an issue for games of this kind.

Some economic interactions have similarly well-defined rules. For example, a sealed-bid second-price auction in which communication between bidders is prohibited has a very simple action (or strategy) space, in which each bidder's set of possible actions consists of the possible values for their bids.[1]

In general, it is necessary to bring to bear extrinsic information about the 'rules of the game' if useful predictions about outcomes are to be obtained. Such information may be either institutional or behavioral. Institutional information may be related to knowledge about the political and economic environment (for example, some 'actions' might be ruled out by law or social

[1] Of course, as with games like poker, individuals may choose to break the rules, incurring the risk of a penalty.

norms). In particular, if the institutional structure allows agents to achieve some outcomes unilaterally, for example by withdrawal, individual rationality provides bounds on the set of feasible outcomes, as shown in Proposition 5.

Behavioral information may involve knowledge about the expectations or decision-making procedures adopted by participants. Perhaps the most useful contribution along these lines is that of Sutton (1997). Sutton argues that empirical evidence on the relationship between the size of the market and the 'toughness' of competition may be used to bound the range of feasible outcomes.

6 Concluding comments

A research program can maintain a flourishing appearance long after its initial hope to provide not merely the capacity to explain the world but to predict and therefore potentially change it has dissipated. Nevertheless, without predictive power a scientific research program must eventually degenerate. Game theory in economics is in danger of meeting this fate.

There are, however, some promising options. With more attention to the determination of the strategy space, incorporating a mixture of institutional analysis and choice theory, the range of outcomes consistent with a reasonable Nash equilibrium may be limited to an extent that allows useful predictions.

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