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An experiment on a core controversy ☆

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ABSTRACT

A longstanding criticism of the core is that it is too sensitive to small changes in player numbers, as in a well known example where one extra seller (resp. buyer) causes the entire surplus to go to the buyer's (seller's) side. We test this example in the lab, using several different trading institutions. We find that successful collusion is relatively infrequent and decreasing over time even with institutions that facilitate collusion and, consistent with core theory, a disproportionate share of the surplus typically goes to the less numerous side. Our study also illuminates the boundaries of competitive equilibrium.

1. Introduction

The concept of the core is generally regarded as the most important contribution to economics made by cooperative game theory. Among other things, it provides a game theoretic foundation for competitive equilibrium (CE). A well known critique of the core, however, is its seemingly excessive sensitivity to small changes in the numbers of players. The standard example is a market game in which each buyer and each seller want to transact a single indivisible unit of a good. All buyers have the same value v and all sellers have the same cost $c < v$. The core predicts a unique outcome when there are unequal numbers of buyers and sellers, namely that all the trade surplus goes to the less numerous side (called the short side hereafter) of the market. In particular, one extra trader on one side shifts the entire surplus to the other side.

The critique holds that this extreme sensitivity is unrealistic. For example, the long side traders (the more numerous group, slated to receive zero payoff) may find a way to collude and seize some of the surplus. Or, as suggested by recent work in behavioral economics, fairness norms might cause traders on either side to reject these extreme allocations. If both forces work in tandem, we might even see fairness-motivated collusion.

In this paper we take the critique to the laboratory. To give collusion its best shot, we examine small number cases, with two or three players on the long side and exactly one fewer player on the short side. Core theory does not specify the

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trading institution, so we look at several. At one extreme, we use standard computerized continuous double auction market (DA-Std henceforth). We also consider two augmentations that provide collusion opportunities. One augmentation (DA-Chat) allows free pre-trade communication in computer chatrooms. Another augmentation (DA-Barg) keeps the chatroom open throughout the trading period and also facilitates and implements collusive profit sharing agreements. Finally, at the other extreme, we drop market-like features and consider a direct negotiation chatroom (Barg) that allows traders to implement enforceable trade agreements.

Section 2 reviews relevant literature. The most closely related laboratory studies are some pioneering market experiments conducted in the 70's, and there are also related experiments in political science and on market competitivity. Section 3 reviews both the cooperative and the noncooperative theories of the core, and notes their implications for our laboratory study. Section 4 lays out our experimental design and the testable implications. Section 5 presents the results, and Section 6 summarizes and discusses implications. On-line Appendix A presents supplementary regressions and robustness checks, Appendix B details the coding of chatroom dialogues and collusion activity, and Appendix C reproduces sample instructions for subjects.

2. Related literature

The core was introduced formally in Shapley (1952) and Gillies (1954), though its conceptual roots go back to Edgeworth (1881). A more recent theoretical literature following Selten (1980) builds noncooperative foundations for the core through constructing noncooperative bargaining games from which core and only core outcomes emerge in equilibrium; see Perry and Reny (1994) for a prominent example, and see the introduction in Yan (2003) for a brief survey. Insights from this recent literature inform our implementation, as noted in section 3.2 below.

In a pioneering series of experiments, Murnighan and Roth (1977, 1978, 1980) tested core prediction for the extreme example (framed as "left-shoe, right-shoe") against other cooperative solution concepts. Using just one short sider and two to eleven long siders and using bargaining institutions far different from ours,[1] they found that better information and communication opportunities fostered more effective collusion among long siders. With two long siders, their short sider on average kept less than 60% of the total surplus in most treatments, and even in their minimal information and communication treatments the short sider seldom averaged more than 70% of the surplus.

About the same time, Fiorina and Plott (1978) launched a laboratory investigation of the core (and other cooperative solution concepts) in voting games. They found the core did a good job of predicting the outcome of majority rule voting, although Eavey and Miller (1984) found that "fair" alternatives outside the core did even better.

Because the core generally contains the competitive equilibrium (CE), the unique core allocation in our example coincides with CE. The next section will discuss theoretical connections, but here it is worth mentioning the empirical literature known as boundary studies of CE. Smith and Williams (1990) report early computerized market studies, including several sessions with identical valuations and identical costs. These sessions featured a continuous double auction market (CDA) with 4 multi-unit buyers and 4 multi-unit sellers and sizable imbalances (either 16 units demanded and 11 units supplied, or the reverse). They found convergence to near the CE, with over 90% of surplus typically going to the short side after 3 or 4 periods. Also inducing identical valuations and identical costs, Friedman and Ostroy (1995) run 4-buyer–4-seller (4×4 hereafter) standard CDA markets with slightly imbalanced demand and supply parameters but with essentially divisible goods, and they found slow convergence towards the CE price. Isaac et al. (1984) allowed one side of a 4×4 market to collude, in the form of a one-time face-to-face free communication for up to 4 minutes when the session was paused, and still found rather competitive outcomes in the CDA. Joyce (1984) studied collusion in a hybrid market institution with some CDA and some Call Market features and reported that buyers were better than sellers at colluding and extracting surplus.

Our experiment differs from those studies in having only 1–3 traders on each side of the market, facilitating collusion. Also, we publicly announce the demand and supply parameters as suggested by core theory, while CE studies typically treats them as private information, so subjects initially may not be aware of their market power.[2]

3. Theoretical background

Intuitively, the core consists of allocations that are stable in the sense that no subgroup of players can break away and achieve better payoffs for all its members.

To formalize, let N denote the set of all players. Any nonempty subset $T \subseteq N$ of players is called a *coalition*, and $|T| \geq 1$ denotes the number of players in T. The *grand coalition* consists of all players, $T = N$. A *characteristic function* is a mapping

[1] They used fixed matchings, unpaid subjects or subjects participating for course credit, and sequences of simultaneous bilateral offers — e.g., one long sider might offer to buy the other long sider's shoe first and if successful then offer to buy the short sider's shoe.

[2] Readers may be reminded of other laboratory experiments that, on closer scrutiny, are less closely related to our experiment. As a counterpoint of their finding of cross-country differences in ultimatum game outcomes, Roth et al. (1991) used 1-seller-versus-9-buyer market games for control, showing that in all the countries the market games lead to the same CE outcome in which all surplus goes to the seller. In their setting, no individual buyer has any impact on the equilibrium price, a crucial difference from our experiment. Like us, Cason and Noussair (2007) studied very thin markets, with only 2 single unit buyers and 3 single unit sellers. But they investigated price dispersion when there were search frictions in Posted Offer markets, an issue almost polar to ours.