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## Cournot competition between teams: An experimental study<sup>☆</sup>

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### ABSTRACT

In the literature on market competition, firms are often modeled as individual decision makers and the internal organization of the firm is neglected (unitary player assumption). However, as the literature on strategic delegation suggests, one cannot generally expect that the behavior of teams is equivalent to the behavior of individuals in Cournot competition. Nevertheless, there are models of team-organizations such that team-firms and individual firms are behaviorally equivalent. This provides a theoretical foundation for the unitary player assumption in Cournot competition. We show that this assumption is robust in experiments, which is in contrast to experimental results on price competition.

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## 1. Introduction

In the literature on market competition such as Bertrand or Cournot competition, firms are modeled as individual decision makers and the internal organization of the firm is neglected. This is known as the *unitary player assumption*. In contrast, studies of the theory of the firm (e.g. Hart, 1995) and personnel economics (e.g. Lazear, 1995; Prendergast, 1999) focus extensively on the internal organization of the firm but the market environment is considered just in a very stylized form. In quantity competition à la Cournot, teams may not display the same behavior as individuals. This is illustrated by the literature on strategic delegation in Cournot oligopoly, where the delegation of a principal to a manager leads to revenue maximization of the firm rather than to profit maximization (see Vickers, 1985; Fershtman and Judd, 1987). This example shows that the behavior of the firm may depend crucially on the interaction within the

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team/firm. Thus from a theoretical point of view, the unitary player assumption does not hold in general in Cournot competition.

In this paper we ask whether there exists some organizational forms of the firm in a Cournot oligopoly generating behavior that is equivalent to the behavior of an individual decision maker. We show in Section 2.1 that with respect to theoretical predictions of behavior this question can be answered in the affirmative. There do exist simple models of firm organizations in Cournot oligopoly with equilibrium behavior that is equivalent to equilibrium behavior of individual decision makers. This provides a theoretical foundation of the unitary player assumption in the Cournot oligopoly. For example, we consider a Cournot oligopoly where members of each firm choose efforts. For simplicity, the efforts of the members in each firm are aggregated additively to the quantity of the firm. We consider two different regimes of distributing the firm's profits among its members. First, profits may be distributed equally per head (treatment SH), an arrangement that may loosely correspond to a co-operative like an Israeli kibbutz or a German Genossenschaft. In a second regime, profits may be distributed proportionally according to each member's costly effort (treatment SP). We observe that in both cases there are Nash equilibrium quantities of the team-firms that are equivalent to the Nash equilibrium in an analogous Cournot oligopoly in which each firm is an individual decision maker. We call this the *behavioral equivalence* of teams and individual decision makers.

The behavioral equivalence is taken as a hypothesis for the subsequent experimental study: the main focus of our paper. We conduct experiments for all profit distribution arrangements mentioned above, as well as a standard Cournot oligopoly, with individual decision makers as control (treatment C). We find that team-firms do not behave significantly different from individual firms. Moreover, in all treatments, average market quantities are not significantly different from the Cournot Nash equilibrium. Thus we cannot reject the hypothesis of behavioral equivalence for Cournot competition.

One fundamental conceptual difference between individual decision makers and team players is that the latter eventually have to resolve an intra-team coordination problem that is trivially absent when the firm consists of one individual only. This intra-team coordination problem is especially severe in treatment SH, where there exists a multiplicity of Nash equilibria, besides the symmetric Nash equilibrium (see Section 2.1 for details). Consequently, a player with teams as opponents may face a larger degree of strategic uncertainty about the opponents' quantities than when she would have individual decision makers as opponents. Pure strategy Nash equilibrium would not predict any differences because, irrespective of whether the opponents are teams or individual decision makers, it resolves probabilistically the strategic uncertainty. I.e., in equilibrium, every player plays a pure strategy best response to her conjecture, that the opponents' play independently from their pure strategy best response. Yet, it seems plausible that because of the intra-team coordination problem, a player who faces team-opponents is "less confident" in her equilibrium conjecture about opponents' play than when she faces individual decision makers as opponents. Lack of confidence in probability judgements is modeled formally in the literature on ambiguity or Knightian uncertainty (see Schmeidler, 1989; Gilboa and Schmeidler, 1989). Recently, such approaches have been applied to strategic games and to Cournot oligopoly in particular (see Eichberger et al., 2008, 2009, for theory and experiments, respectively). It has been shown that if players are averse to ambiguity, then their best response decreases in the amount of strategic uncertainty. Based on these results, we hypothesize that subjects facing team-opponents play on average lower quantities than subjects facing individual decision makers as opponents. To test this hypothesis, we design treatment AH that is analogous to treatment SH, except that one of the firms in each market consists of just one subject. We find that average quantities of individual firms in treatment AH do not differ significantly from those in treatment C. Thus, we do not find support for our hypothesis that the intra-team coordination problem may lead to strategic ambiguity.

The article is organized as follows. Section 2 introduces the experimental design and procedures. The experimental results are described in Section 3. We conclude with a discussion in Section 4, in which we also discuss the related literature. A translation of the instructions to the subjects is included in Appendix A.

## 2. Design

### 2.1. Treatments and theoretical predictions

Our model of market competition is a symmetric 3-firm Cournot oligopoly in which every firm faces the linear inverse demand function

$$p(Q) = \max \left\{ 500 - \frac{1}{6}Q; 0 \right\}, \quad (1)$$

where  $Q = \sum_{j=1}^3 q_j$  is the sum of all firms' quantities  $q_j \in \mathbb{R}$ ,  $j = 1, \dots, 3$ . Each firm has unit marginal costs, i.e.  $c = (q_j) = q_j$  for all  $q_j \in \mathbb{R}$ . The profit function of firm  $j = 1, 2, 3$  is given by

$$\pi_j(q_j, q_{-j}) = (p(Q) - 1)q_j, \quad (2)$$

where  $q_{-j} = \sum_{h \neq j} q_h$  denotes the sum of quantities of firm  $j$ 's opponents.

Let  $F_j$  be the set of members of firm  $j$ . Each firm  $j = 1, 2, 3$  is viewed as a team of members  $i_j \in F_j$ . Member  $i_j$  of firm  $j$  chooses the effort level  $e_{i_j} \in \mathbb{R}$ . For all treatments,  $q_j = \sum_{i_j \in F_j} e_{i_j}$ . That is, the quantity of each firm is the sum of its members' efforts.

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