Bertrand colludes more than Cournot

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Abstract

On the basis of evidence of past oligopoly experiments, we argue that there is often significantly more tacit collusion in Bertrand price-choice than in Cournot quantity-choice markets.

Keywords: collusion, quantity-choice and price-choice experiments.

1 Introduction

An important issue in industrial organisation is the incidence of tacit collusion. Given that Bertrand price competition and Cournot quantity competition are the two workhorse models in IO, a natural question is whether one is more prone to tacit collusion than the other. Somewhat surprisingly perhaps, this issue has not been explicitly addressed in any experiments.

Based on a survey of experimental IO research, Holt (1995) hypothesises that in Cournot settings there is less collusion than in Bertrand settings. However, apart from Fouraker and Siegel (1963), referred to as FS in what follows, the studies on which this hypothesis is based have either Cournot or Bertrand treatments, but not both.

Recently, a series of papers have investigated the impact of information feedback on behaviour in Cournot and Bertrand settings (see Huck et al., 2000; Davis, 2002; Altavilla et al., 2003, further referred to as HNO, Davis and ALS, respectively). As a by-product, the underlying data allow for a direct comparison of the tendency to tacitly collude between Cournot and

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Bertrand environments with two and more sellers. In the present paper we review the evidence and find support for Holt's hypothesis.

2 Overview of experimental designs

FS, HNO, Davis and ALS examine the impact of information on behaviour in experiments in which subjects play repetitions of static Cournot and Bertrand games. The reported experiments have similar designs and contain BASIC and EXTRA treatments[1]. In the BASIC treatments only aggregate information was provided on the competitors' quantities or prices and no information about their profit. In the EXTRA treatments detailed information was provided on all individual quantities or price and profits[2].

Although there are differences in experimental procedures between the four studies with respect to type of matching, information about duration and number of players, these procedures are the same across Cournot and Bertrand treatments *within* each study. Moreover, the experiments all have linear demand and cost functions except for FS who implement an homogenous good environment. Table 1 summarises specific features and provides an overview of the theoretical benchmarks that correspond to the parameter choices in the four sets of experiments (C refers to Cournot and B to Bertrand)[3]. In the FS, HNO and ALS experiments, theoretical benchmarks are the same across BASIC and EXTRA.

In all studies except FS the number of rounds is known, so strictly speaking, the unique Nash equilibrium of the repeated game corresponds to repeated play of the unique Nash equilibrium of the stage game. However, from earlier studies we know that even in finitely repeated games, players manage to cooperate to some degree and behave similarly as in infinitely repeated games (see Selten and Stoecker, 1986; Normann and Wallace, 2004). One measure for the scope for tacit collusion in a repeated game is the ratio between the gains from cooperation and the gains from defection, $\frac{\pi_{\text{JPM}} - \pi_{\text{Nash}}}{\pi_{\text{Defect}} - \pi_{\text{JPM}}}$, which in the table we refer to as the *Friedman* index after

[1]The Cournot and Bertrand experiments of FS are discussed in part three of their book. BASIC refers to their incomplete information treatment and EXTRA to their complete information treatment. For ALS, BASIC and EXTRA respectively refer to their ED 1 and ED 3 treatments.

[2]In the BASIC treatments of FS subjects were not informed about their competitors' profit function. In the four EXTRA treatments of FS the competitors' profit could be calculated on the basis of profit tables, apart from the Cournot triopoly treatment, where only the sum of the competitors' profit could be calculated.

[3]ALS ran two Cournot treatments which we call C1 and C2.

	FS duopoly		FS triopoly		HNO		Davis		ALS		
	C	B	C	B	C	B	C	B	C1	C2	B
# players	2	2	3	3	4	4	4	4	2	2	2
# rounds T	22	15	22	15	40	40	40	40	20	20/15	20
duration	not known		not known		known		known		known		
matching	fixed		fixed		fixed		fixed		random		
$p^{\text{BASIC}}_{\text{Nash}}$	0.8	0.5	0.6	0.5	76.5	39.25	57	57	8	9.6	8
$p^{\text{BASIC}}_{\text{JPM}}$	1.2	3.5	1.2	3.5	151	151	113.1	129	12	12	12
$q^{\text{BASIC}}_{\text{Nash}}$	20	26	15	17.33	74.5	86.92	56	56	16	14.4	16
$q^{\text{BASIC}}_{\text{JPM}}$	15	14	10	9.33	49.67	49.67	37.3	32	12	12	12
$\pi^{\text{BASIC}}_{\text{Nash}}$	16	0	9	0	5550	3238	3136	1344	128	138.2	128
$\pi^{\text{BASIC}}_{\text{JPM}}$	18	36	12	20	7400	7400	4181	3072	144	144	144
$\pi^{\text{BASIC}}_{\text{Defect}}$	20	83	16	83	9867	16915	5575	7022	162	150	162
$p^{\text{EXTRA}}_{\text{Nash}}$							81	57			
$p^{\text{EXTRA}}_{\text{JPM}}$							129	129			
$q^{\text{EXTRA}}_{\text{Nash}}$							48	56			
$q^{\text{EXTRA}}_{\text{JPM}}$							32	32			
$\pi^{\text{EXTRA}}_{\text{Nash}}$							2304	1344			
$\pi^{\text{EXTRA}}_{\text{JPM}}$							3072	3072			
$\pi^{\text{EXTRA}}_{\text{Defect}}$							4096	7022			
Friedman	1	0.77	0.75	0.32	0.75	0.44	0.75	0.44	0.89	0.96	0.89
slope	-1/2	1	-1/2	1	-1/3	1/7	-1/3	1/7	-1/2	-1/4	1/4

JPM = joint profit maximising; slope = slope of reaction curve

Table 1: Summary of features of Cournot/Bertrand experiments

Friedman (1971). The higher the index, the higher the possibility that tacit collusion can be sustained as an equilibrium in an infinitely repeated game context as part of a grim trigger strategy. Martin (1995), van Wegberg (1995) and Potters et al. (2004), for instance, use this index to measure the scope for tacit collusion. It is clear from table 1 that on the basis of this index one would *a priori* expect that the tendency to tacitly collude is higher in Cournot than in Bertrand treatments. For ALS one would expect the same tendency to cooperate when comparing C1 with B.

3 Degree of tacit collusion

In this section we examine to which extent behaviour in Bertrand and Cournot treatments deviates from the Nash prediction towards the fully collusive (joint profit maximising) level. The degree of collusion of oligopoly k in round t is defined as follows:

$$\rho_{kt} = \frac{\bar{p}_{kt} - p_{\mathrm{Nash}}}{p_{\mathrm{JPM}} - p_{\mathrm{Nash}}}, \tag{1}$$

where $\bar{p}_{kt}$ is the average price of oligopoly k in round t[4]. If $\rho_{kt} = 0$, duopoly k makes Nash choices in round t and if $\rho_{kt} = 1$, duopoly k makes JPM choices in round t. If $0 < \rho_{kt} < 1$ the choice of duopoly k in round t lies between the Nash and the JPM level and if $\rho_{kt} < 0$ the choice is more competitive than the Nash level.

Table 2 provides averages and standard deviations referring to cross-sectional variability of the degree of collusion for the different experiments[5]. Also included in the table for each experiment are p-values of Mann-Whitney-U tests of $H_0 : \bar{\rho}_{\mathrm{Cournot}} = \bar{\rho}_{\mathrm{Bertrand}}$ based on independent data[6].

Table 2 shows that average degrees of collusion are higher in Bertrand

[4]For the Cournot treatments the price of each oligopoly member is calculated on the basis of the inverse demand function taking into account that $p_i \geq 0$. Another option would be to calculate the degree of collusion on the basis of the quantity decisions and benchmarks. As long as prices calculated on the basis of inverse demand curves and quantities calculated on the basis of demand curves are not below 0, both alternatives give the same result. In the Cournot treatments of the FS experiments and in the HNO and Davis experiments zero prices and quantities had to be enforced because calculated prices and quantities were sometimes below 0. This adjustment results in slight differences in degrees of collusion, depending on whether calculated on the basis of prices or quantities. However, all analyses based on the degree of price or quantity collusion yield exactly the same conclusions. With respect to the Bertrand treatments in the FS experiments, larger differences naturally occurred whether the degree of collusion was measured on the basis of the price choices or the calculated quantities, because the profit function defined in terms of quantities is not a linear transformation of the profit function defined in terms of prices (due to the homogeneous good environment). Yet, even with respect to FS, the conclusions of the tests are exactly the same, whether based on the degree of price or quantity collusion. From ALS we only have subject-specific decisions, such that the degree of collusion in their Cournot and Bertrand treatments is respectively calculated on the basis of quantity and price choices.

[5]Only pre-merger data from Davis are used for our purposes since post-merger data are *ex ante* asymmetric.

[6]The ALS data are subject-specific (cf. random matching) and thus strictly speaking not independent within the treatments. In another version of the paper, the same authors also report on an EXTRA (ED 3) treatment with fixed matching and it seems that this treatment yields the same conclusions (see Altavilla et al., 2005).

	BASIC		EXTRA	
	$\bar{\rho}_{1 \text{ to } T}$	N	$\bar{\rho}_{1 \text{ to } T}$	N
FS duopoly				
Cournot	-0.12 (0.16)	16	-0.24 (0.70)	11
Bertrand	0.24 (0.15)	17	0.52 (0.26)	10
p-value	0.000	33	0.002	21
FS triopoly				
Cournot	-0.24 (0.18)	16	-0.25 (0.19)	11
Bertrand	0.09 (0.07)	17	0.18 (0.06)	10
p-value	0.000	33	0.000	21
HNO				
Cournot	0.01 (0.03)	6	-0.23 (0.15)	6
Bertrand	0.04 (0.07)	6	0.04 (0.06)	6
p-value	0.394	12	0.004	12
Davis				
Cournot	0.14 (0.54)	5	-0.50 (0.09)	5
Bertrand	-0.10 (0.02)	5	-0.05 (0.03)	5
p-value	0.151	10	0.008	10
ALS				
Cournot1	-0.70 (0.82)	18	-1.50 (0.48)	20
Cournot2	-1.30 (0.47)	18	-2.19 (0.57)	22
Bertrand	0.75 (0.43)	18	-0.14 (0.19)	22
p-value1	0.000	36	0.000	42
p-value2	0.000	36	0.000	44

Standard deviations are in brackets.
N = number of independent observations for FS, HNO and Davis and number of players for ALS.

Table 2: Average degrees of collusion in Cournot/Bertrand experiments and test statistics of $H_0 : \bar{\rho}_{\text{Cournot}} = \bar{\rho}_{\text{Bertrand}}$

than in Cournot treatments in all possible comparisons except one[7]. Under BASIC information conditions in the experiment of HNO, the difference is in the 'right' direction but is not significant, while the difference is highly significant under BASIC in FS and ALS. Under EXTRA information conditions, the difference between Cournot and Bertrand settings is for all experiments highly significant.

The finding that Bertrand environments are more prone to tacit collusion

[7]The same conclusions are obtained on the basis of other subsets of rounds.

that Cournot environments is clearly in contrast to what the *Friedman* index predicts, thus other explanations should be looked for.

One possible explanation is that under EXTRA information conditions, where detailed information is provided on the success of competitors, imitation of the most successful competitor drives the difference between Cournot and Bertrand settings. Indeed, Bertrand-Nash equilibria are much closer to imitation equilibria than Cournot-Nash equilibria implying that degrees of collusion calculated in imitation equilibria are *a priori* higher in Bertrand games (HNO, Davis and ALS calculate imitation equilibria). This may especially have played a role in the EXTRA treatments of the HNO and Davis experiments, where groups consisted of four players and subjects only had a profit calculator and no profit tables (Selten and Ostmann, 2001). However, the imitation argument is less compelling under BASIC information conditions because subjects are then unable to identify the most successful competitor.

An alternative explanation is provided by the indirect evolutionary model of Bester and Güth (1998) who find that the scope for altruistic (cooperative) preferences is larger in games of strategic complements (cf. Bertrand games) than in games of strategic substitutes (cf. Cournot games). In other words, the type of strategic interdependence (strategic substitutes versus complements) may be important in determining the degree of tacit collusion (see also Rotemberg, 1994).

4 Conclusion

On the basis of experimental data from oligopoly experiments with Cournot and Bertrand treatments, we find statistical support for the suggestion of Holt (1995) that there seems to be more tacit collusion in Bertrand price-choice than in Cournot quantity-choice experiments.

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