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Are Imitative Strategies Game Specific? Experimental Evidence from Market Games

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ARE IMITATIVE STRATEGIES GAME SPECIFIC? EXPERIMENTAL EVIDENCE FROM MARKET GAMES

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Abstract

This paper studies imitation in price and quantity markets. We analyse the results of two experiments designed with different information settings. The analysis shows that information is used differently and has diverse effects according to the market under investigation.

Keywords: *Cournot, Bertrand experiments, imitation*

J.E.L. classification: C91, D83.

Introduction[§]

Whenever possible, individuals tend to mimic the choices of more successful agents. In market models, imitation theory, (see, among others, Schlag, 1998, Vega-Redondo, 1997) suggests different equilibrium selection processes according to how imitation behaviour is modelled and what information is available for players. For example, if agents operate in one market and observe (and imitate) the successful actions of their direct rivals, then imitation will lead to the selection of the Walrasian equilibrium (Vega-Redondo's theory). By the same token, if players receive feedback information on the average industry-wide profit (Karandikar *et. al.,* 1998), imitation may lead markets to become collusive over time (*aspiration* rules). To date, there are several experimental papers testing the different theories (see C. Altavilla *et al.* 2006, for references). In a recent paper (J. Apesteguia, *et al.* 2006), a general framework to study imitation in markets is developed and tested in Cournot games. Their main finding is that informational signals are a key-factor in explaining the different effects of imitation. In this paper we take a different perspective. Our main hypothesis is that imitative behaviour may differ according to the market model under investigation. In other words, comparing Cournot and Bertrand markets we may observe different effects of the same informational signals, due to the specific structure of the market game[1]. We report data from two market experiments; in each experiment we consider two different information structures and matching protocols. In the first setting, players are located in the same market throughout the session and they only observe prices/quantities and payoffs of their own market (fixed

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[1] The existence of differences in behaviour and equilibrium convergence between price and quantity games has already been explored in the experimental literature: see J. Potters, *et. al.* (2006).

matching and partial information setting, FM, hereafter). In the second setting, players are randomly allocated to different markets in each period; in this context, they have access to the statistics of all existing markets, including their own (random matching and complete information setting, RM, hereafter). The FM setting is compatible with Vega-Redondo's theory of imitation ("imitating your opponent's best strategy"), whilst in the RM setting alternative rules are possible. As before, agents behaviour may respond to informational signals from their own market – using the previous imitation rule, or they may imitate "the best performer in all markets", inducing a more collusive market outcome[2]. The evidence suggests three main conclusions. First, in both Bertrand and Cournot market games, there is only a small difference between the two informational settings, i.e., the speed of the fall in prices and profits is similar in the two settings in Cournot and, for Bertrand markets, is only very slightly greater in the FM setting than in the alternative design. Second, responsiveness to market information signals is game specific. In Cournot markets, players are generally more responsive to signals than in the Bertrand games. Furthermore, in the latter model, individuals are more reluctant to decrease prices, even if such a strategy has proved to be beneficial to another player in the recent past. Third, the type of imitative behaviour also varies with the market game. Under quantity competition, players respond to signals coming from both their direct opponents and the overall 'best market performers'. In the price competition setting, participants are significantly influenced only by differences in their payoffs and the profits accruing to the "best performers".

[2] A similar rule can be found in J.Potters *et al.*, (2002), where agents may adopt an imitation strategy defined as "follow the exemplary firm". Under this imitation regime, the authors prove that the process of equilibrium selection leads Cournot markets to become more collusive in the long run.

Experimental Design

The experiments are based on two types of duopoly market models. In the first case of quantity competition, market demand and individual profits are represented by the functions:

$$p_i = a - b(q_i + \theta q_j)$$
$$\pi_i = (p_i - c)q_i$$

The second case considers a model of price competition:

$$q_i = \alpha - \beta(p_i - \theta p_j)$$
$$\pi_i = (p_i - c)q_i$$

Table 1 reports the value of the demand coefficients in the two market models[3]:

Table 1: Values of the Demand coefficients

	A	b	θ	α	β	θ
COURNOT D.P.	24	$\frac{2}{3}$	$\frac{1}{2}$			
BERTRAND D.P.				24	2	$\frac{1}{2}$

Note that:

$\alpha = \dfrac{a}{b(1+\theta)}$ and $\beta = \dfrac{b}{b^2(1-\theta^2)}$;

Marginal cost were zero.

Table 2 reports the corresponding values of equilibrium prices (quantities) and profits. The experiments were conducted in Siena (2002-2004) and the subjects were undergraduate and graduate students. Participants were paid according to their cumulative performance during the experiment (observed profits varied between 8 and 12 Euro per subject). Each market game lasted 20 rounds.

[3] See C. Altavilla *et al.* (2006) for an illustration of the market models.

Table 2: Equilibrium values

	BERTRAND			COURNOT		
	p	q	π	p	q	π
WALRAS	6	18	108	6	18	108
NASH	8	16	128	9.6	14.4	138.2
JPM	12	12	144	12	12	144

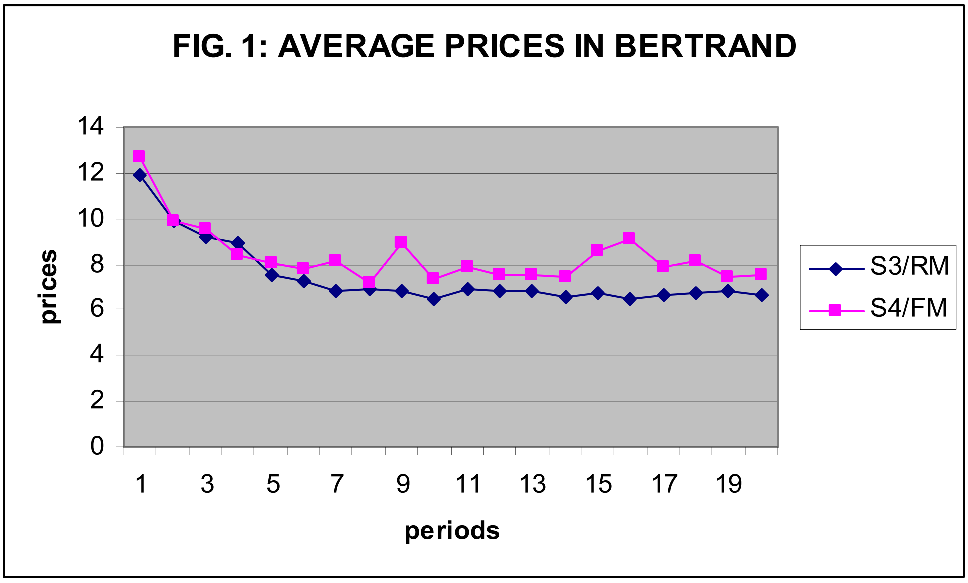
The number of participants varied between 20 and 22 – 84 subjects, in total - (10 or 11 active markets per period), and the experiments consisted of four sessions: S1/RM: a Cournot game with 11 markets per day; S3/RM: a Bertrand game with 11 markets; S2/FM: a Cournot game with 10 markets, and , finally, S4/FM: a Bertrand game with 10 markets per period.[4]

Participants were informed on the value of the demand parameters and costs. Specifically, in each stage, they could choose a level of output (price) in the interval 0-24 (only integer values) and, the maximum value of the aggregate output at which individual profits would be zero was clearly indicated on the computer screen. Instructions varied according to the information settings.

Convergence

We begin by considering the Bertrand markets. In S3/RM, mean prices settled in the interval 6.5-7; whilst in S4/FM, prices settled in the Nash interval, ranging from 7.5 to 8, in the three final periods (Figure 1). Further insight on the individual behaviour is provided by the mean relative frequencies of the price strategies (for the last three periods) in the different equilibrium intervals.

[4] S1/RM lasted only 15 periods.

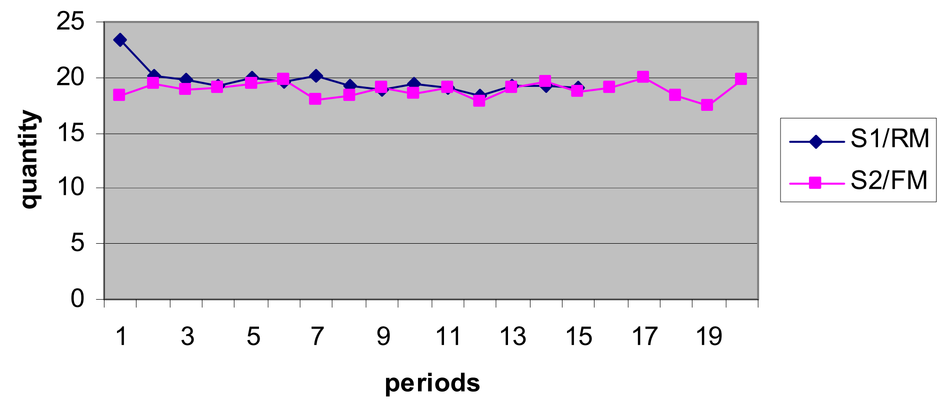


In the S3/RM setting, the mean frequency of the Walrasian price p=6, was 30.3%, whilst the Nash choices (p=8) corresponded to 15.3% of the total; finally, Collusive prices (p=12) corresponded to only 1.5% of the total. In the S4/FM context, however, the average frequencies of the Nash and collusive prices were significantly higher (20% and 6.7%, respectively) than under FM although the Walrasian strategy remained the most common (21.7%).

Turning to Cournot, average quantities are higher in S1/RM than in the alternative context, converging to the value of 19 in the final period (Figure 2). In S2/FM the average quantity converged to values closer to the Walrasian outcome in periods 18 (q=18.4) and 19 (q=17.4), and then increased to q=19.8, in the final stage. In S1/RM, the average frequencies (for periods 12-15) of the strategies in the interval 17< q <19 corresponded to 68.3% of the total, while only the 5% of the total were in the Nash interval 13 < q < 15, no player chose strategies close the to Collusive equilibrium value of 12, and the average frequency of q > 19 corresponded to 26.7%.

In S2/FM, though the average frequency of the strategies in the Nash interval was lower than in S1/RM (1.6%), the frequency of strategies in the Collusive interval of 11-13 was of 11.7% of the total. Strategies in the Walrasian interval 17-19 corresponded to 38.4%, whilst the average frequency of $q > 19$ corresponded to 48.3%.

FIG. 2: AVERAGE QUANTITIES IN THE COURNOT MARKETS



Imitation

What use did players make of all information available in S1/RM and S3/RM? In order to analyse the imitative behaviour in these contexts where alternative rules are possible, we studied the determinants of participants' strategy changes. Specifically, we estimated a random effects probit model of the following form:

$$(1)\ \mathrm{Prob}\left(S_{i,t} \neq S_{i,t-1}\right) = \Phi\left[\alpha + \beta_1\left(\pi_{j,t-1} - \pi_{i,t-1}\right) + \beta_2\left(\pi_{\max,t-1} - \pi_{i,t-1}\right) + \beta_3\left(\pi_{i,t-2} - \pi_{i,t-1}\right)\right]$$

Where i subscripts refer to individuals, j to the direct opponent and t the period. S stands for strategy, π for profits (with $\pi_{\max,t-1}$ indicating the profits of "the best performer in all markets" in the previous period), α and β parameters (along with the variance of the random effects) to estimate and Φ the standard normal distribution. Our model allows three types of behavioural response: an "imitate the opponent" rule, an "imitate the best performer in all markets" rule and a basic reinforcement rule, given by the change in the individual's profits over the two previous periods. The first two columns of Table 3 report the results from separate estimations of the Bertrand and Cournot RM games, whilst the third column reports the estimated difference in coefficients from a model estimated conjointly.

Table 3: Imitation in RM market games, Random Effects Probit model.

	Model estimated		
Explanatory variable	**Bertrand**	**Cournot**	**Bertrand & Cournot – estimated difference in marginal effects**
Direct Opponent's Profits	-.02 (.36)	1.39** (.62)	1.44* (.077)
Best Performer's Profits	.83*** (.27)	1.51** (.60)	.95*** (.48)
Own Previous performance	-.02 (.28)	-.23 (.28)	-.27 (.42)
LR test of random effects	27.7***	5.9***	33.2***
n	396	286	682

Note: The table reports marginal changes evaluated at the mean of the dependent variable (with jacknife standard errors in brackets). ***, **, * indicate statistical significance at the 1%, 5% and 10% levels respectively. Coefficients and standard errors are all multiplied by 100.

Examining Table 3, we can see that imitative behaviour is much less pronounced in Bertrand than in Cournot markets: in fact, the coefficients are smaller and less frequently statistically significant in the price game than in the quantity game. Moreover, the difference between the two experiments is statistically significant for both imitation variables. In the Cournot game, individuals change their strategies in response of both signals, whilst in the Bertrand game, players react only to the industrial signal. Finally, the effect of the reinforcement rule on the dependent variable is not statistically significant in either experiments, though the coefficient is higher in the price game.

Conclusions

In common with previous work, our results confirm that players are more reluctant to change prices than quantities. In terms of imitative behaviour, players in Bertrand markets are generally less responsive to informational signals; they don't respond to the strategic behaviour of their direct opponent, and their reaction to the 'best market performer' is around half as strong as in Cournot markets. The implication of our analysis is that much more attention should be paid to the nature and rules of the strategic context we are exploring when studying imitation behaviour. Focussing only on the relative effects of alternative informational structures may be misleading, if the games specific structures are not carefully taken into account.

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