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Second Mover Advantage and Bertrand Dynamic Competition: An Experiment

May 2010

LABSI WORKING PAPERS

N. 28/2010

SECOND MOVER ADVANTAGE AND BERTRAND DYNAMIC COMPETITION: AN EXPERIMENT[§]

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Abstract

In this paper we provide an experimental test of a dynamic Bertrand duopolistic model, where firms move sequentially and their informational setting varies across different designs. Our experiment is composed of three treatments. In the first treatment, subjects receive information only on the costs and demand parameters and on the price' choices of their opponent in the market in which they are positioned (matching is fixed); in the second and third treatments, subjects are also informed on the behaviour of players who are not directly operating in their market. Our aim is to study whether the individual behaviour and the process of equilibrium convergence are affected by the specific informational setting adopted. In all treatments we selected students who had previously studied market games and industrial organization, conjecturing that the specific participants' expertise decreased the chances of imitation in treatment II and III. However, our results prove the opposite: the extra information provided in treatment II and III strongly affects the long run convergence to the market equilibrium. In fact, whilst in the first session, a high proportion of markets converge to the Nash-Bertrand symmetric solution, we observe that a high proportion of markets converge to more collusive outcomes in treatment II and more competitive outcomes in treatment III. By the same token, players' profits significantly differ in three settings.
An interesting point of our analysis relates to the assessment of the individual behavioural rules in the second and third treatments. When information on the behaviour of participants on uncorrelated markets is provided, players begin to adopt *mixed behavioural rules*, in the sense that they follow myopic best reply rules as long as their profits are in line with the average profits on all markets, and , when their gains fall below that threshold, they start imitating successful strategies adopted on other markets.

Key words: *price competition, learning, strategic information*.

J.E.L. classification: C90, C91.

[§] We thank G. Pomitallo (SUN) and F. Lomagistro (University of Siena) for technical assistance. The research was financed by Miur. The experiments were designed using Z-tree (U. Fischbaker, University of Zurich).

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Introduction

A relevant area of research in theoretical and applied Industrial Economics is related to the existence of market leadership.

The empirical literature has provided evidence on the consequences that leadership has on market efficiency, as well as on the individuals' firm success and profits.

F.D. Scherer and D. Ross (1990), for example, examine the effects of leadership in several industry case studies and the main results of their analyses are that average prices tend to be higher in the sectors where there are leaders, and leading firms are more profitable than opponents.

Furthermore, several papers have identified the conditions which may create leaders' advantages or disadvantages (see M. B. Lieberman and D. Montgomery, 1988, 1998).

Amongst the key factors which have been identified it is worth mentioning the roles played by the firms' R&D activity, the asset markets and the greater possibilities leaders have to create buyers' switching costs.[1]

Assuming firms are able to fully exploit the profits of the R&D activities, in fact, leaders may gain competitive advantages both by gaining a higher experience in the innovative process and by acquiring a larger number of patents and licences. Second, in industrial sectors where capital assets are scarce, leaders may pre-empt competitors thus gaining advantages. Finally, it is a well known result that firms may create consumers' switching costs through marketing and advertising policies, thus creating and preserving competitive advantages over their rivals.

Some countervailing factors, however, may constitute leaders' disadvantages, in as much as they can be easily imitated (especially in R&D activities and marketing policies)

[1] There are several reasons why firms can become market leaders (see M. B. Lieberman and D. Montgomery, 1988, 1998). Leaders in a specific industry can be, for example, early entrants in the industry which have better exploited market opportunities, or incumbent firms which have gained leadership through superior abilities in specific areas. Even luck can play an important role.

and some of their experience can be transferred onto competitors who can free ride and therefore enjoy lower costs and lower risks in their productive activity.

Summing up, the empirical studies have examined both cases in which leaders can have relevant competitive advantages and cases in which followers or late entrants can on the contrary exploit superior opportunities.

Also the theoretical analyses have focussed on the possible existence of first or second movers advantages.

The theoretical aspects of market leadership have been studied in settings in which incumbent firms move sequentially. In sequential move games, the classical example of the existence of first movers advantages is depicted by the von Stackelberg model of quantity competition. In her seminal papers, E. Gal-Or (1985, 1987) has examined, however, the conditions under which leadership accrues either to firms which move first or to firms which observe the rivals' choices and then respond and they are therefore second movers in the sequential setting. Gal-Or concludes that in the case in which reaction functions are upwards sloping (as in the Bertrand case), there are followers' advantages; on the contrary, when reaction functions are downwards sloping, leaders' are more profitable than followers as in the von Stackelberg model.[2]

Compared to simultaneous settings, sequential move games also hold quite different predictions as far as market efficiency and firms' individual profits are concerned.

In the case of strategic substitutes as in the von Stackelberg model, market efficiency is higher in the sequential setting than in the simultaneous game and first movers earn more than second movers (who earn less than in the simultaneous game); in the case of strategic complements as in the Bertrand sequential price game, market efficiency is lower in the latter setting and second movers gain higher profits than first movers, although both firms earn higher profits compared to the simultaneous game.

A related area of the economic literature focuses on the issue of endogenous timing, thus extending the theory of oligopoly to models that analyse the firms' endogenous choice of roles (first or second movers), as well as the firms' endogenous choice between simultaneous or sequential play.[3]

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[2] See also M. Boyer and M Moreaux (1987).
[3] See S. Dowrick (1986); E. van Damme and E. Hurkens (1998); J. Hamilton and J. Slutsky (1990).

In a recent paper, R. Amir and A. Stepanova (2006) provide a more general insight in the field of Bertrand games, both by relaxing some of the assumptions of the model (e.g., profit concavity) and by considering the case of asymmetric cost functions. One of their more interesting result is that when both reaction functions are upwards sloping, if unit costs are sufficiently different then the low cost firm has a greater incentive to be the first mover; in the opposite case (unit costs are sufficiently close) then the low cost firm has a higher incentive to act as the follower. By the same token, the high cost firm always prefers to be the follower.[4]

Despite the large body of experimental research on dynamic symmetric duopolies, the experimental evidence on sequential games is scant. Some papers have however focussed on the existence of first and second movers advantages in market experiments, under different structural and informational conditions.

As far as the von Stackelberg setting is concerned, two papers have explored the issue of first movers advantages and the welfare implications of this specific setting.

S. Huck, W. Müller and H. Normann (2001) compares two market mechanisms as in the cases of Cournot and von Stackelberg's models. The aim of their research is to test whether – as theory predicts – the sequential game structure yield higher welfare results compared to the simultaneous one. In their experiments they consider two different types of matching protocols (fixed vs. random pairs), showing that in the fixed matching protocols Cournot markets tend to be more collusive than in the opposite case of random matching, thus confirming C. Holt (1985) early results. In the von Stackelberg scenario, however, the level of output and the consumers' surplus is higher than in the Cournot markets, regardless of the specific matching mechanism.

In W. Güth, W. Müller and Y. Spiegel (2002), the effects of different information structures on the existence of first movers advantages in a quantity setting are studied.

As the authors summarize in their conclusions, when followers are informed of leaders' choices with higher probability, the competitive advantage of leaders tends to be higher, but followers also tend to over-react, producing above the optimal level. Uninformed followers, on the contrary, produce as predicted by the theory.

[4] R. Amir and A. Stepanova's paper explores many more issues, considering the cases in which reaction functions are upwards or downwards sloping.

The paper that is closer to our research project is D. Kubler and W. Müller (2002), in which several cases of sequential price competition in duopoly markets are examined. The experiments comprise a large number of designs, and the main research questions regard the existence of second mover advantages compared to the Bertrand simultaneous game, adopting fixed vs. random matching protocols. An important aspect of D. Kubler and W. Müller (2002) is that second movers are required to indicate an entire range of responses to their opponent's choices, according to the strategy method. This point of the experimental design allows the authors to measure the differences both in efficiency and in the players' behaviour across treatments.

In the paper presented here we study a model of dynamic sequential Bertrand competition. Our main research question however is to test whether the players' behaviour changes in relation to the type and amount of information provided. For this reason, our experiments comprise three different sessions, in which the information sets vary. In one setting (Treatment I), subjects receive information only on costs and demand parameters and on the price' choices of their opponent in the market in which they are positioned; in the second and third treatments, subjects are informed also on the behaviour of players who are not directly operating in their market. Specifically, in Treatment II, players could have information on the prices of first and second movers in all the other markets; [5] in Treatment III, one second mover was placed in two different (and separated) games, thus facing two different first movers, and the three players were informed on the prices on both markets. In both treatments, information was accessible at no cost by participants. As specified above, we wish to study whether second mover advantages and the process of equilibrium convergence are affected by the specific informational setting adopted.

There is now a substantial body of the experimental literature on market games which stresses the importance that strategic information (i.e., information the individuals have on the actions of other agents on their same market or operating on different markets) often has on individuals' behaviour and on long run market efficiency (see: Huck et al., 1999, 2000; Altavilla et al. 2006, for reference). The basic idea of these approaches is

[5] They could also view some statistical measures such as the average price and profit of first and second movers on all markets.

that information affects the individual learning process and decision rules inducing imitative behaviours which in turn affect the degree of competition\collusion on markets (M. Armstrong and S. Huck, 2010).

Our experiments aim at providing a test of such conjecture in a sequential price game.

The experimental designs adopted here differ from the ones previously mentioned in several aspects. First, we consider only the case in which participants face the same opponents throughout the entire game (fixed matching); second, an important aspect is that students had experience of market models and industrial organization, conjecturing that both the fixed matching protocol and the students' expertise on market games would decrease the chances of imitation in treatments II and III.[6]

Our main results are that the amount and type of strategic information provided strongly affects the long run convergence to the market equilibrium. In fact, whilst in the first treatment, a high proportion of markets converge to the Nash-Bertrand sequential solution, we observe that a high proportion of markets converge to more collusive outcomes in Treatment II and more competitive outcomes in Treatment III. By the same token, players' profits significantly differ in the alternative settings.

Finally, studying the students' answers we see that strategic information greatly improve the understanding of the game in Treatment II, but observing a different player in the same role (Treatment III) generates an imitative process that determine a decrease in prices.

The paper is organised as follows. In the first section we introduce the theoretical model adopted and the experimental designs. Section 2 reports the aggregate analysis of the experimental evidence, studying the process of convergence to the market equilibrium in the three different settings, as well as comparing the extent of the second movers' advantages in the three scenarios. Section 3 deals with the individuals' choices, introducing econometric models which are used to study individuals' behaviour in the second and third treatments. Section 4 concludes.

[6] Specifically, all the participants were Economic students who had studied Microeconomics and Industrial Oraginization.

1. Theoretical background and experimental predictions.

We consider a dynamic model of price competition, in markets where products are differentiated and where the direct demand function is:

$$q_i = \alpha - \beta(p_i - \theta p_j) \qquad \textbf{(1)}$$

unit costs were equal to zero.

Agents interacted for an exogenously fixed number of periods and their profit function was equal to:

$$\pi_i = (p_i - c)q_i \qquad \textbf{(2)}$$

Students were informed on the values of the coefficients of (1) and they knew how many periods the game would last.

Assuming competition takes place in a number of duopolistic markets and setting the values of *α*, *β*, *θ* equal to 24, 2, and ½ , respectively, Table 1 reports the theoretical sub-game perfect equilibrium benchmarks both in the case firms move simultaneously and in the case they move sequentially, with firm *i* being the first mover and firm *j* being the second mover and leader in the market.

TABLE 1: Theoretical equilibria endpoints

	P	***π***
Walras	**6**	108
Nash-Bertrand	8	128
Collusion	12	144
Sequential (*i, j*)[7]	10; 9	129, 133

The experiments were designed as a number of duopolistic markets and each student was allocated to one market at the beginning of the session. The computer randomly selected a role (A or B) and the subject knew that A players would move first and B

[7] In the case of sequential equilibrium, following Gal-Or (1985), the equilibrium price vector slightly differ from the reported values. However, given that the prices may take only integer values, these values turn out to be higher than the theoretical equilibrium at (10, 9).

players would be the second mover throughout the entire game. We adopted the experimental design used in Huck et al., 2000 and C. Altavilla, et al., 2006, in as much as participants were informed on the values of the demand coefficients, and they were told for which prices consumers' demand for their goods (and profits) would be equal to zero. Furthermore, they could use a profit calculator which enabled them to try out strategies and to measure the expected profits.[8]

Our sample is constituted by 75 students of the University of Naples II and Siena, and they were enrolled among the second and third year students in the faculties of Economics of both Universities. Each participant gained one token for each profit point (the exchange rate was equal to one Euro cent per token). At the end of the experiment, the total payoff of each individual was equal to the cumulated profits that individual had gained through the ten stages the game lasted. On average, students were paid between 11 an 13 Euro and the experiments lasted 45 minutes.[9]

TABLE 2: The Experiments

Experiments	N. of Markets	N. of stages	N. of subject	Strategic Information
Treatment 1	**13**	**10**	**26**	**NO**
Treatment 2	**14**	**10**	**28**	**YES**
Treatment 3	**14**	**10**	**21**	**YES**

Before the experiments started, we took a particular care in making sure students fully understood the software and the structure of the competition. In fact, in order to isolate the effects of information and to minimise errors due to the understanding of the model or

[8] Instructions are available on request. We did not use the strategy matrix as in Kübler et al. 2002, because we wanted to minimise any possible constraint on the understanding of the models; we wanted to focus on the impact of the information on the subjects' choices. As a matter of fact, in the ex post de-briefing most subjects reported that the profit calculator was very useful.

[9] In the third treatment, we manipulated the exchange rate of the A players, so that their payoff was only slightly higher the B players; all the exchange rates were common knowledge.

the software we allowed three trial periods and participants were encouraged to ask questions on specific points.[10]

An important aspect of our experiments relates to the design of strategic information.

In Table 3 we briefly describe the differences, as far as strategic information is concerned, across the three treatments.

TABLE 3: The design of strategic information

1) **TREATMENT 1: NO STRATEGIC INFORMATION: subjects were informed only on the costs and demand functions.**

2) **TREATMENT 2: COMPLETE STRATEGIC INFORMATION: subjects received complete information on the choices of all participants (first and second movers) in their session, along with information on costs and demand.**

3) **TREATMENT 3: PEER EFFECTS WITHOUT PAYOFF EXTERNALITIES: one second mover faced opponents in two different markets and the three players observed each other choices (demand and costs functions were common knowledge).**

Both in the cases of treatments II and III, the type of strategic information provided is not assumed to have any influence on behaviour, according to the standard game theoretical approach to sequential price competition. The fact that agents faced the same opponent in each market should make information on other markets even more irrelevant to the single player's choices. As noticed in the introduction, however, there is a large body of empirical evidence that shows that firms in real industries do make use of all available information on prices and competitive strategies that are employed in other sectors. By the same token, several experimental studies have proved that such information affects both the process of equilibrium convergence and the individuals' selection of strategies. We hypothesise that also in the case of the sequential game setting such information might have an influence on convergence and behaviour either

[10] Students were finally required to fill a short questionnaire explaining their strategies : in fact, on their screen a single question asking to explain their choices would appear, and they were allowed using a maximum of 70 words. We introduced the questionnaire in order to understand their actions, as a matter of fact we use their replies to analyse the experimental evidence.

because it may speed up the players' learning process and because it may affect the players' imitation process. We therefore state the following experimental hypotheses:

H1: *If strategic information plays no role in the individuals' decision making process, then equilibrium will converge to the subgame perfect equilibrium values (SPE) (see bottom row in Table 1).*

H2: *If the information on other players affects the subjects' learning process we may observe that the equilibrium may not converge to the SPE equilibrium value, and the individual pricing behaviour differ in the three settings.*

2. Aggregate data analysis and market convergence.

Table 4 reports the average values of the prices and profits in the three treatments, along with some relevant statistics.

TABLE 4: Average prices and profits in the alternative treatments

Treatment	Rounds	Prices first mover		Prices second mover		Profits first mover		Profits second mover	
		Median	*Mean*	*Median*	*Mean*	*Median*	*Mean*	*Median*	*Mean*
T1 no info	All	8.00	9.92	7.00	9.05	108	118.28	112	127.60
			(5.14)		(4.02)		(37.14)		(37.35)
	8,9,10	**6**	**8.18**	**6**	**7.90**	**112**	**117.77**	**119**	**120.49**
			(0.32)		(0,35)		(0.60)		(2.44)
T2 with info	All	10	10.27	9	9.33	120	116.39	136	134.68
			(3.72)		(3.19)		(32.07)		(33.31)
	8,9,10	**9.5**	**9.74**	**7.5**	**8.45**	**116**	**111.74**	**138**	**135.17**
			(1.71)		(0.19)		(15.43)		(9.54)
T3 2 followers	All	10	10.51	9	8.95	132.5	127.23	128	124.53
			(3.73)		(3.06)		(37.21)		(33.14)
	8,9,10	**8.5**	**8.59**	**8.5**	**8.38**	**128**	**125.18**	**130.05**	**127.13**
			(.27)		(.08)		(4.13)		(1.78)

Legenda: Standard deviations in parenthesis

In Treatment 1 and 3 average prices settle – in the last three round – in the interval of the symmetric Bertrand and sequential Bertrand equilibrium and are consistently lower than in Treatment 2. It is worth noticing that, in the latter design, average prices are higher than at the sequential Bertrand equilibrium point throughout the ten rounds the experiment lasted. One interesting aspect is to evaluate the differences in the price dynamics for the two types of players. In fact, whilst the average prices of first movers – over the ten periods – are substantially similar in the three treatments, as for second movers, average prices are significantly lower in treatment three. Also, the rate at which prices decline differ for A and B players: first movers in Treatment I and III decrease their prices more than in treatment two, whilst the opposite appears to be the case for second movers. In fact, in treatment three second movers decrease their prices in the early stages of the game and their behaviour settles down rather quickly. Furthermore, looking at median prices, it is clear that the information helps the process of convergence in as much in the two treatments – considering the last stages of the game - median and average prices are closer than in the control group. Also the profit dynamics differ across the three treatments. In Treatment II, the average profits in the final stages of the game approximate the equilibrium profits at the sequential Bertrand point, and first movers' profits decline whilst second movers' profits increase overtime. The same pattern exists in treatment three but profits are lower than in equilibrium for both types of players; in treatment one, however second movers' profits decline overtime.

Summing up, Table 4 indicates that information affects the price and profit dynamics, but the direction of the effects differ according the specific informational setting. In both cases, the information improves the understanding of the rules of the game, the process of convergence of the prices is faster than in the control group, moreover second movers advantages increase overtime. However, in treatment two prices are consistently higher than in the other setting and also the leaders' profits are closer to the Nash equilibrium prediction than in final treatment.

Both the facts that there are substantial differences in the price dynamics across treatments and the that there are differences in the process of convergence to a market equilibrium are shown in Table 5 and Figures 1, 2 and 3. In Table 5, we report Mann-Whitney tests comparing the price dynamics for the three designs, whilst in Figures 1, 2 and 3 we report the frequency of markets converging to one of the different equilibrium benchmarks.[11]

[11] In Figure 1, 2 and 3 we consider the average prices (in the last three periods) in each market which converge, within an interval of ± 0.5, to one of the equilibrium benchmarks reported in Table 1.

Table 5: Mann-Whitney results

Mann Whitney results		
Hyphotesis	z	Prob > lzl
Ho: **FMT1 = FMT2**	3.362	0.0008
Ho: **FMT1 = FMT3**	3.509	0.0005
Ho: **SMT1 = SMT2**	3.211	0.0013
Ho: **SMT1 = SMT3**	1.774	0.0760

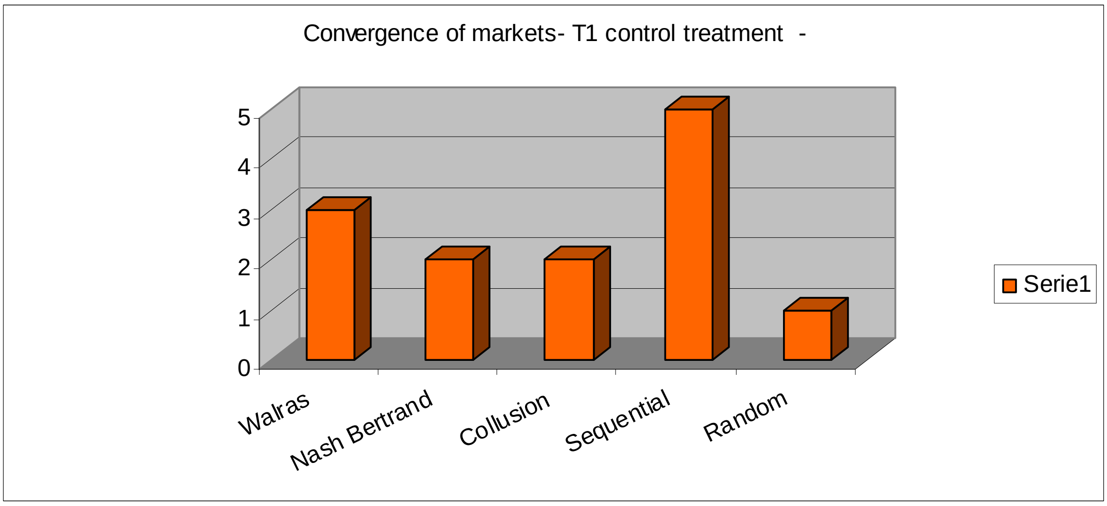

Figure 1

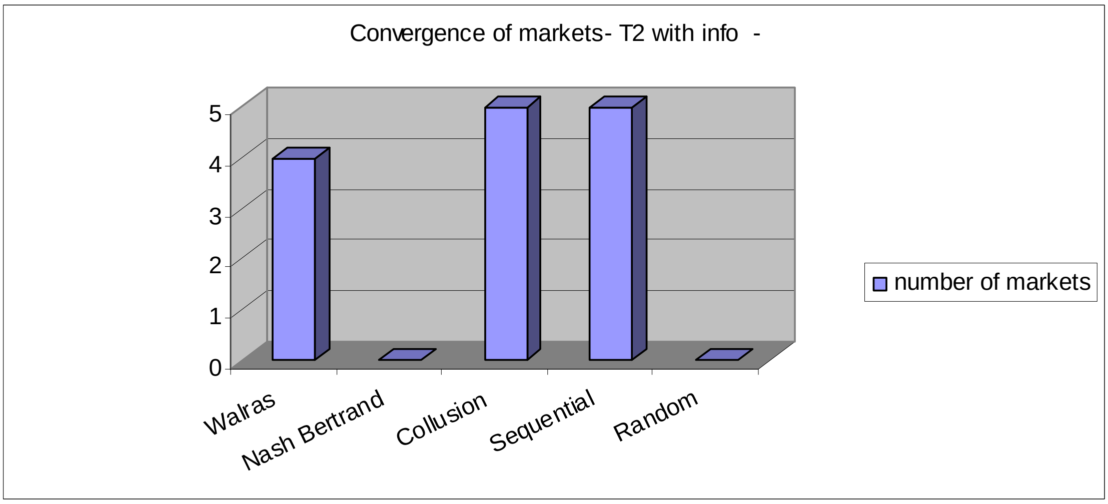

Figure 2

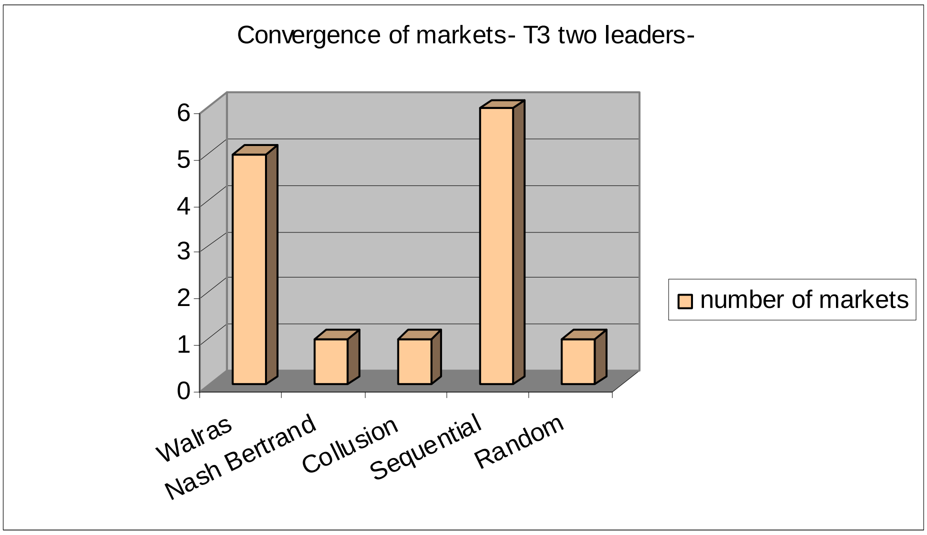

Figure 3

The results of the Mann-Whitney tests show that – for all comparisons – the null hypothesis is always rejected and therefore we can conclude that behaviour in the three markets consistently differ in accordance to the informational setting.

More interestingly, Figures 1, 2 and 3 show the effects that the different pricing behaviour produce on the market lung run efficiency. Here, whilst the number of market converging to the sequential equilibrium is the almost the same in the three treatments, markets which converge to collusion vary between 5 per cent of treatment three to 37 per cent of treatment two. On the contrary, markets which converge to the Walrasian equilibrium vary between 23 per cent in treatment one to 37 per cent in treatment three.

Therefore, as it was shown in Table 4, information has different effects on behaviour in T2 and T3, thus affecting the average profits, the leaders' competitive advantage and, in turn, the market level of efficiency. From what it has been said so far, we are then able to state our first result that provide a preliminary answer to the first and second research hypotheses.

Result 1: General information on the pricing behaviour of players on different markets and on the pricing behaviour of a leader on one different market has significant effects on the process of equilibrium convergence, both affecting individuals' behaviour and market long run performance. However, these effects go in opposite directions: in T2, information produce an increase in the pricing decisions of both players and an increase of average profits; in T3, information induces a decrease of the leaders' pricing choices and a decrease of average profits for both players.

3. The impact of information on individuals' pricing behaviour.

In the previous section we have assessed the differences in long run efficiency in the three treatments. An important point of the data analysis is to evaluate the role played by the information settings on the individuals' choice process. We focus our attention on Treatment II and Treatment III in turn. As it will be recalled, in Treatment II, players had access to all information regarding all markets in the specific session.[12]

In Treatment III, one second mover was placed in two different markets and the three players could observe each other's choices. The structure of the informational setting was therefore as follows:

$$\mathbf{FM_1 \leftrightarrow FM_2}$$

|

|

SM

[12] The information was continuously available (starting from the second period onwards) and was free of charge: participants could view the table containing the individual data and some statistics (average profits per market and per player) for each period just pressing a button on the screen. We recorded the number of times each player pressed the button. It must be also specified that, overall, the general information table was used very often: out of 28 players only two never looked at the table and eight subjects used the information between 8 and 10 times.

In order to better understand the process of convergence, in what follows we take a closer look at individual behaviour in the three settings.

As a first step in the analysis (Table 6 and 7), we make the hypothesis that players behave in the same way in all the settings, following myopic best reply rules, according to the reaction functions:

$$p_t^{fm} = a + bp_{t-1}^{sm} + v_i + e_{it} \quad \textbf{(3)}$$

For the first mover, and,

$$p_t^{sm} = a + bp_t^{fm} + v_i + e_{it} \quad \textbf{(4)}$$

For the second mover.[13]

It may be observed that for both first and second movers, the reaction function is closest to the theoretical best response (Gal-Or, 1985) in the case of Treatment II where information is available on other players' prices and profits. One may observe that whilst for TI and TIII the difference from the theoretical (myopic) best response is statistically significant, for TII it is not (for the first mover and the intercept of the second mover).

However, also comparing TIII and TI the results show differences between the treatments.

Such differences are confirmed if we estimate the reaction functions of first and second movers jointly in the three designs and we then compare the estimate of the full model with the estimates of the restricted models, as we do in Tables 8 and 9.

[13] Specifically, the Tables report the results of the estimation of GLS models with ar(1) autocorrelated error terms.

TABLE 6: Reaction functions - first movers in the three treatments – including t-test of difference from (myopic) best response

		T1		**t-test on Diff from theoret. MBR**	**T2**		**t-test on Diff from theoret. MBR**	**T3**		**t-test on Diff from theoret. MBR**
		Coeff	**Std. Error**		**Coeff**	**Std. Error**		**Coeff**	**Std. Error**	
	Price SM	***0.60***	0.08	**2.27**	***0.44***	0.09	1.06	***0.69***	0.08	***2.89***
	Intercept	***3.59***	0.78	-1.55	***5.88***	0.92	-0.06	***3.21***	0.76	*-1.82*
n		117			126			126		
R-sq	**Within**	0.25			0.12			0.23		
	Between	0.86			0.70			0.91		
	Overall	0.36			0.19			0.46		

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01***, **p <.05**, *p<.10*, p ≥.10

TABLE 7: Reaction functions - second movers in the three treatments – including t-test of difference from best response

		T1		**t-test on Diff from theoret. MBR**	**T2**		**Diff from theoret. MBR**	**T3**		**t-test on Diff from theoret. MBR**
		Coeff	**Std. Error**		**Coeff**	**Std. Error**		**Coeff**	**Std. Error**	
	Price SM	***0.62***	0.03	***5.49***	***0.48***	0.06	**2.11**	***0.62***	0.05	***3.89***
	Intercept	***3.00***	0.43	***-3.51***	***4.39***	0.65	-1.24	***3.04***	0.53	***-2.77***
n		130			140			140		
R-sq	**Within**	0.78			0.43			0.54		
	Between	0.96			0.69			0.92		
	Overall	0.78			0.46			0.66		

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01***, **p <.05**, *p<.10*, p ≥.10

TABLE 8 : Joint estimation of first mover reaction function.

	Full model		Restricted model	
	Coeff	z	Coeff	z
Price SM (b_1)	***0.61***	12.00	0.64	14.70
PSM T2 (b_2)	-0.11	-1.33	*-0.14*	-1.82
PSM T3 (b_3)	0.11	1.15	-	-
T2 (a_2)	**1.84**	2.26	**1.99**	2.58
T3 (a_3)	-0.66	-0.66	-	-
Intercept (a_1)	***3.50***	6.85	***3.35***	7.62

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01***, **p <.05**, *p<.10*, p ≥.10

TABLE 9: Joint estimation of second mover reaction function.

	Full model		Restricted model	
	Coeff	z	Coeff	z
Price FM (b_1)	***.62***	16.73	***.61***	20.39
Price FM T2 (b_2)	**-.13**	-2.11	**-.13**	-2.20
Price FM T3 (b_3)	-.01	-.14	-	
T2 (a_2)	*1.36*	1.86	*1.26*	1.88
T3 (a_3)	.22	.30	-	
Intercept (a_1)	***2.99***	6.43	***3.08***	8.56

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01***, **p <.05**, *p<.10*, p ≥.10
3)The models estimated are, Full Model:

$$p_t^{sm} = a_1 + a_2T_2 + a_3T_3 + b_1p_t^{fm} + T_2b_2p_t^{fm} + T_3b_3p_t^{fm} + v_i + e_{it}$$

And Restricted model (only T2 effects):

$$p_t^{sm} = a_1 + a_2T_2 + b_1p_t^{fm} + T_2b_2p_t^{fm} + v_i + e_{it}$$

Are the differences reported in the reaction functions due to the effects of the external information?

In order to answer the question, we consider Treatment II separately and in Tables 10 and 11 we estimate the reaction functions of two separate groups of subjects, one who accessed the information rarely and another group who consulted the Table very often. In fact, whilst almost all players used this facility sometimes, there was much difference in the regularity with which they did so. In the Tables, we divide the sample into "high" and "low" information players according to the frequency with which they requested information on others[14]. Looking at the first movers, one may observe , for the "low" group, the remarkable similarity of the reaction function to that estimated for TI (no information) first movers. On the other hand, "high" information first movers behave quite differently, reacting less to the second mover's previous price. The differences in the coefficients in the two models are clearly both statistically significant.

Second movers on the other hand do not seem to change their behaviour very much when confronted with information on others' prices and profits. The values of both intercept and reaction to first mover's price are not statistically different with or without

[14] Specifically, "low" and "high" information players were defined by splitting the sample at the median number of times information was requested.

information suggesting that overall, information does not affect play as much for second movers. One obvious reason for this may be the relatively straightforward computation – and lack of uncertainty – regarding the optimal reaction. However, also in the case of second movers, the function is much closer to the theoretical prediction compared to the alternative settings. [15]

TABLES 10 AND 11: Reaction functions estimated separately for low and high information players

10: Reaction function, First mover

T2		Low Info		t-test on Diff from theoret. MBR	High Info		t-test on Diff from theoret. MBR	t-test on Diff between coefficients
		Coeff	Std. Error		Coeff	Std. Error		
	Price SM	***0.63***	0.15	1.31	*0.18*	0.10	-0.35	***3.06***
	Intercept	***4.34***	1.48	-0.56	***8.19***	1.03	1.06	***-3.04***
n		63			63			126
R-sq	**Within**	0.18			0.02			0.17
	Between	0.71			0.74			0.65
	Overall	0.25			0.11			0.25

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01***, **p <.05**, *p<.10*, p ≥.10

11: Reaction function, Second mover

T2		Low Info		t-test on Diff from theoret. MBR	High Info		t-test on Diff from theoret. MBR	
		Coeff	Std. Error		Coeff	Std. Error		
	Price FM	***0.44***	0.07	1.40	***0.51***	0.09	1.53	
	Intercept	***4.59***	0.83	-0.85	***4.43***	1.00	-0.79	
n		70			70			
R-sq	**Within**	0.39			0.46			
	Between	0.83			0.69			
	Overall	0.44			0.49			

[15] It is interesting to notice that if we compute the proportion of subjects who played according to the theoretical reaction function in the three settings, it is possible to see that the highest proportions for both A and B players are in T2.

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01,*** **p <.05,** *p<.10,* p ≥.10

The main result of the previous analysis is that , in Treatment II and III , behaviour differs from the basic treatment and the myopic best reply rule which underline the reaction function models does not explain entirely the subjects' pricing decision. Thus, the differences in the pricing dynamics are dependent on the information settings.

The natural question is therefore: what rule of behaviour is induced by the external information in TII and TIII? Moreover, do agents adopt the same rules in the two different settings?

In what follows, we focus our attention on the first movers' choices in TII and TIII. The reasons why we specifically analyse only the first movers are twofold. First, second movers in TIII do not have access to any external information and therefore the direct comparisons of the two treatments is not possible in their case; second , as it is shown in Table 11, in TII, it is proved that B players – even when available - are less affected by the external information compared to their co-players.

We try to find an answer to the initial question in two subsequent steps. First, we estimate (in Table 12) an "augmented" dynamic reaction function for TII and TIII , assuming that A's behaviour is driven both by the observed actions of their market opponent and by the impact of the external information.[16]

Specifically, the following functions were estimated for first movers:

$$\left| p_t^{FM} - p_{t-1}^{FM} \right| = \alpha + \beta \left| p_{t-1}^{SM} - p_{t-1}^{FM} \right| + \gamma(\pi_{t-1}^{FM} - \overline{\pi}_{t-1}^{other\ fm}) + \varepsilon_t$$

In TII, $\overline{\pi}_{t-1}^{other\ fm}$ term refers to the mean profits of other players, where information was requested. In TIII it was simply the profits of the other first mover in the other market. The estimates suggest that in both T2 and T3 first movers react to both the previous leader-follower price difference and the observed past profit difference. On this, one may observe that, for TII, both maximum and mean profits were tried, however the former were never statistically significant.

[16] We assume that the impact of the external information corresponds to a "satisfying" rule, in the sense that individuals change their price whenever their profits fall below the overall average profit.

TABLE 11: The dynamic "augmented" reaction functions – first movers in TII and TIII

	TII		TIII	
	Coeff	**z**	**Coeff**	**z**
Lagged Price difference (β)	***0.53***	5.25	***0.78***	6.73
Lagged Profit difference (γ)	**-0.02**	-2.23	***-0.02***	-4.28
Intercept	***1.69***	3.20	***0.96***	3.73

Notes: 1) GLS random effects estimates with ar(1) errors.
2) Statistical significance is indicated as follows: ***p < .01,*** **p <.05,** *p<.10,* p ≥.10

Two interesting aspects can be underlined. First, the "augmented" reaction functions have – in both cases – a higher level of statistical significance compared to the previous reaction function models; second, both coefficients , β and γ, have the same magnitude indicating the effect of the external information is similar in the two contexts.

As a second and final step, we look at the individual decision in a probabilistic framework in line with the approach taken by, for example, Apesteguia et al. (2007). In this, we are assuming that – in line with the results of the augmented reaction functions – individuals use "mixed behavioural rules" best responding to their opponent, but "keeping an eye on what is happening on the other markets".

That is, we estimate the probability that the first mover changes her price as a function of three forces: 1) her past profit; 2) the lagged difference in price between first and second mover on the market in which she is operating; 3) the difference in profits between the player herself and either the mean of other players (TII) or the single other player (TIII). The results are shown in Table 12.

TABLE 12: Random effects dynamic probit model of the probability of changing price-first movers – Mixed Behavioural Rules

First Mover	**TI**		**TII**		**TIII**	
	Coeff	**Std. Error**	**Coeff**	**Std. Error**	**Coeff**	**Std. Error**
Lagged Own Profit	*-0.012*	0.006	**-0.009**	0.004	-0.004	0.004
Lagged Price difference	*0.393*	0.207	**0.183**	0.090	***0.325***	0.109
Lagged profit difference	-	-	0.003	0.005	**0.005**	0.002
Intercept	**1.704**	0.780	**1.321**	0.558	*0.841*	0.471

Notes: 2) Statistical significance is indicated as follows: ***p < .01,*** **p <.05,** *p<.10,* p ≥.10

The results suggest that for TII that other profits are playing a less significant role directly, but rather the movement depends on the price difference. In TIII, however, there is evidence that first movers tend to respond directly to the profits of their colleague in the other market. [17]

We are now able to state the second result of our analysis.

Result 2: There are clear differences between the players behaviour in the three treatments; these differences can be identified in the nature of the information available to players. Both in TII and TIII, behaviour changes as effect of the external information and agents use mixed behavioural rules. However, while in TIII there is clear evidence of imitation, in TII, the information on other markets partly affects the individuals' behaviour by improving their understanding of the game, and partly by inducing imitation.

[17] To be more precise, In TIII there is clear evidence that first movers follow the behaviour of the other unrelated first mover in the companion market; in TII the relation to the information available is more complex – in this regard, estimations not reported here suggest that, although the profit difference does not seem to influence the probability of changing one's own price, once the change occurs, the likelihood of moving to the reference price (of the best performing first mover) is influenced by the profit difference.

4. Concluding remarks

In this paper we presented a market experiment in which firms moved sequentially, information was complete and the participants were skilled in the area of Industrial Organization. Our working hypothesis was that we would observe that the prices converged to the sequential equilibrium values, and the players would use best reply rules in all the settings. However, we observe that the external information provided in TII and TIII affects the price dynamics in a significant way. The main reason is because even "expert" subjects tend to imitate, when their performance is not in line with the profits other players are gaining on other markets.

There are three consideration we would like to make. First, on the theoretical point of view, we find clear evidence of the existence of price leadership in all settings, thus confirming the previous results of Kubler et al. (2002).

Second, the extent of the leadership may depend on the way several sources of information available to firms and managers on a market interact.

In fact there can be a crucial effect on efficiency played by external sources of information, which are assumed to be of importance even by skilled players.

Finally, there is a behavioural aspect we would like to underline, and it is related to the question whether "experts" – such like managers – would be less naïve decision makers than other agents (say, consumers) since they are specifically trained at taking complex decisions as profit maximising actions (Armstrong and Huck, 2010). Here, our results seem to hint that imitative behaviour may settle in as a result of strategic uncertainty (i.e., uncertainty on the type of player you are competing on the same market) rather than cognitive constraints, thus contradicting the answer to the question.

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