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ABSTRACT

Reciprocity and Learning Effects in Price Competition*

One disputed topic in Organization and Management economics is how leadership and collusive agreements are set and maintained in industries where firms are characterised by similar technological opportunities and structures. This topic is particularly important to analyse online and digital markets, which can be regarded as networks where managers share information and where there are no structural differences among firms. In this paper we claim that strategic advantages may be the outcome of repeated interaction among managers and can be driven by two (in some cases) competing forces, information and reciprocity. In fact, on one side, full information on all firms' strategies, help agents to coordinate their decisions and drive the final outcomes towards more profitable solutions. On the other side, when information is limited only to their direct opponents, competitive advantages are maintained when each competitor views the individuals' share of profits as a "fair" allocation. Thus, pricing behaviour is affected both by the willingness to reciprocate the opponent behaviour and the willingness to imitate best strategies observed in other markets. Both pricing behaviours lead to different profit outcomes. We test our hypotheses with a lab experiment on a sequential pricing game. We find a striking difference in pricing behaviour across treatments, and a significant difference also in the ability of the second movers to establish and keep their leadership. Specifically, individuals are highly competitive when information on other players' prices is limited, and only in few markets we observe second movers' advantages. When information on prices on all markets is provided, the picture is entirely different, and prices are very close to the sub-game equilibrium level. Overall, reciprocity can explain the results, however, full information reduces negative reciprocity and competition.

JEL Classification: C90, C91, L1

Keywords: price competition, learning direction theory, trust and reciprocity

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Introduction

In the last thirty years, there has been an unprecedented increase in the provision of online and digital markets (OECD, 2022). In many economic studies, both in the fields of Managerial and Industrial Economics, such development has been seen as an extremely positive event since it creates more opportunities for consumers' welfare. Also, it was supposed that such phenomenon would produce a decrease in monopolistic and collusive practices, which were considered more common in traditional industries.

More recently, the enthusiasm has long subsided. The large effect on consumers' welfare has been reduced by the imperfect implementation of the use of big data and availability of accessing all world markets (Calvado and Polo, 2021). Similarly, even excluding the paradox of market power practices of web giants and platforms, also in small and local digital industries (for example, food deliveries, local transportation, etc.) it is very difficult to detect anti-competitive conducts and tacit producers' agreements.

How competitive advantages are set and maintained has always been one of the most disputed topics in Organization and Management Economics. Many empirical and theoretical studies have provided results which often consistent and mainly based on technological and strategic opportunities incumbent firms face in their specific markets.

For example, as far as firms' market power is concerned, many papers provided evidence on the consequences of leadership for market efficiency, as well as on individual firms' success and profits. Scherer and Ross (1990) examine the effects of leadership in several industry case studies finding that average prices tend to be higher in sectors where there are leaders and that leading firms are more profitable than their opponents. Furthermore, several papers have identified the conditions which may create leaders' advantages or disadvantages (see Lieberman and Montgomery, 1988, 1998).

The main results in this field are that – in order to enjoy market power and success – firms need to have technological and cost advantages (barriers to entry, scale economies and so forth), both in the production/ factors' markets and in the financial sources.

Similarly, the existence and the stability of tacit collusive agreements have been largely studied both at an empirical and theoretical level. Also in this context, barriers to entry, cost opportunities play important roles, whilst, as far as the theory is concerned, long run strategic interactions may favour cooperation among rivals.

An important aspect is underlined in the theoretical models, and it is referred to the existence of strategic opportunities, that is the possibility for firms to pre-empt rivals by moving first (or second as in price and in innovation competition).

To this day, empirical and theoretical research, however, fail to identify how in digital markets, strategic advantages and cooperation seem to emerge and stabilize even in industries (as for online markets) where competitors share the same technological opportunities and the same cost structure. In other words, when managers do not have any specific premium over competitors, how successful firms emerge and – sometimes – their leadership is accepted even by rivals with similar opportunities? Alternatively, how competitors manage to collude even in circumstances where fierce competition should be the short and long run market outcome?

The issue of what are the underlying factors enhancing collusive agreements and leadership in online markets is now an important topic for American and European Antitrust policy.

In fact, a clear identification of the working factors underlying collusion and leadership in the new digital industries - that may help the design of anti-monopolistic policies - is still missing.

The problem is even more difficult because such market conducts cannot be detected by applying the usual theoretical and empirical tools, that were used to study collusion and market power in traditional sectors.

Quite recently, a new area of research has focussed on a behavioural perspective which can provide useful answers to the above-mentioned questions.

In a seminal paper, Armstrong and Huck (2010) state relevant aspects of firms' conducts that may lead to collusion and to leadership (or, on the contrary, to fierce competition) which are not related to any structural or strategic opportunity but are based on strategic and behavioural codes.

If we consider an industry as a social network, for example, group identity, trust and reciprocity can foster cooperation, while reputation can even make leadership an accepted outcome for all competitors.[1]

[1] In fact, the crucial aspect of the definition of group identity applied to Management and Industrial Economics is re-defining an industry as a network of agents who repeatedly interact among themselves in several market activities (innovation, advertising, etc.). Many elements may enhance group identity in markets. Relevant points are sharing the same educational networks or previous labour experiences, as well as the connection through social media. These points may be useful in increasing what Armstrong and Huck (2010) define as *esprit des corp* and in sharing the same information.

In this new context, trust, reciprocity and reputation can be built even when there are none of the structural conditions reported before.[2]

If these components of managers' behaviour are present in an industry, then the stability of agreements as well as the acceptance of market leadership can be seen as the effects of the evolving nature of market interactions.

More specifically, group identity can improve trust among competitors, increasing reciprocity. Reciprocity is the expectation that trust will be reciprocated by all agents. For example, a firm is willing to forgo short run profits to fulfil an agreement only if it expects all other firms to behave in a similar way. Hence, trust and trustworthiness can be the main ingredients for stable agreements, when the absence of credible threats or expected punishments make defection more probable.

Reciprocity can enhance profits, when agents coordinate their strategies in a collusive manner, but, on the contrary, the lack of trust can lead to fierce competition and negative reciprocity; in this case, agreements are not a stable equilibrium of the market interaction. [3]

A further important factor which is extremely relevant for building agents' reputation, is the opportunity of repeated interaction. When firms interact over a long-time horizon, two new elements can come into play. Firstly, managers' experience increases as effect of a learning process. More expert managers may actually learn how to play more profitable strategies. Secondly, repeated interaction lowers the level of strategic uncertainty, since agents are more likely to understand and predict rivals' behaviour and anticipate their actions. Both the increase in the expertise and the ability of understanding and predicting the behaviour of competitors are likely to have an effect on firms' reputation. If a rival is particularly competitive (or more willing to cooperate) is an assessment which can be made only observing the rival's behaviour overtime.

One crucial factor which is conducive to trust and reputation is the level of information which is available to agents. The study on the effects of information in markets and networks is a well-established area of research in the behavioural literature. The basic point is to show how market performance and firms conducts can change as mere effect of the informational settings.[4]

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[2] In the psychological literature, group identity is strictly related to the self-image and the image of others, and to the decision whether to join a group which shares the same identity characteristics (see Tajfel and Turner, 1979).

[3] The relationship between group identity, reciprocity and competition has been widely studied in the past. For reference, see Bauernschuster et al, 2010.

[4] The connection between information and reciprocity has already been studied in a wide range of industries and research fields, such as steel, microconductors, and also in academic research (see Haussler et al. 2014). As noted in:Ganglmair et al.; 2020, "potential future reciprocity is weighed against the current loss of competitiveness. Individuals are willing to incur the potential costs of sharing valuable information if they expect to receive something of similar value in return".

The main result is that when firms are able to access a wide range of information on their rivals' performance, then profits increase as effect of a more efficient coordination among competitors. Dufwenberg annd Gneezy (2000) study the effects of different sources of information in first-price auctions and find that a wider level of information comprising bids from previous auctions improve the coordination among bidders and bids tend to be higher than in the alternative setting, where information was absent. They conclude that – learning about past biddig behaviour – help competitors to coordinate their action in the present bids, and past optimal bids serve as market signals that facilitate coordination.[5]

Signalling, learning but also the ability to build up a reputation as a cooperator rather than a fierce competitor are the reason why information on markets has a strong impact on behavior.

Many research investigations study the mechanism through which information works; one theoretical approach explains the effects of information using the Learning Direction Theory (Bruttel, 2009). According to this approach, information acts a signal that evidentiate the best performing strategies over time. Managers who are able to obtain full information on all possible strategies learn how to play optimal strategies by directing their choices towards successful choices played in previous rounds. The connection between this learning effect and reciprocity is that – in the full information settings – negative reciprocity which selects strategies leading to competition and profits' destruction tend to progressively disappear.

In Ganglmair, et al.; 2020, agents are willing to share information if they expect their opponents to reciprocate. Therefore, reciprocity and information create a "feedback loop" that affects the efficiency of the strategic interaction.
Specifically, in a repeated centipede game, players are more willing to share information if they expect their opponents to behave in a similar manner. Similarly, reciprocal behaviour which increase expected profits make information sharing more valuable.

The existence and the effects of "feedback loops" is a growing area of research, both in managerial and behavioural studies (see Caputo et al.; 2018; Hildebrandt et al.; 2020). The main results in these studies confirm the basic intuition that there is a connection between the learning effect provided by the information and level of trust and fairness propensity of managers.

[5] Dufwenberg and Gneezy (2000) found similar results in price experiments where subjects could view only their own competitor price (in one setting) and the prices chosen by all subjects in the session in the alternative setting (full information). In this latter setting, prices approached the collusive threshold in the final periods of the game.

However, to date, though these factors are very relevant in online industries, there are no formal analyses on how feedback loops can be created in markets and how they can help to explain collusion and market power.

In this paper, we study the relationship between reciprocity and information in a repeated market game where agents compete in price. The whole industry is divided in *n* duopoly markets, where firms share the same cost structure and face the same demand schedule.

Our theoretical model is set on a sequential price game, where the equilibrium outcome comprises market power and leadership. However, positive reciprocity may lead to cooperation and collusion, whilst negative reciprocity may induce lower prices and competition.

Furhermore, we study the existence of a feedback loop when agents are able to access information on prices on all *n* duopoly markets. We test our theoretical hypotheses with a laboratory experiment, which comprises three treatments.

In the T0 and T1 treatments, we examine the "all or nothing" information structures already studied in Guth et al.; 2006, applying them to the price sequential game. Specifically, in T0 subjects could only view the per-period profits in their own market, whilst in T1 subjects could view both profits and prices (always limited to their own market).

In the T2 treatment we consider the information structure which has been previously considered in Dwefenberg and Gneezy; 2000 and 2002.

In fact, in the T2 treatment, subjects, in each period, in addition to prices and profits in their own market, were allowed to access a table in which they could view the pricing decisions in the remaining *n-1* markets in the previous periods.[6]

We find that the pricing dynamics are completely different in the three contexts. In T0, prices are well below the sub-game equilibrium and the strategic advantage of the follower does not exist. The scenario in T1 is very different. There is a robust evidence of the existence of coordination (positive reciprocity) and leadership, although negative reciprocity and competition is still the prevailing outcome in the majority of markets.

Finally, in T2, we find evidence of strategic advantages and collusion in almost all markets, whilst negative reciprocity and competition are reduced. In our empirical model, we test whether

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[6] In our experiments, we adopt a partner design, i.e.; subjects are allocated to a single market and to a specific role at the beginning of the session, therefore we regard the information concerning other players allocated to other markets as non-strategic in the sense that it has no direct effect on their profits, but can have effects on their learning process and can generate herding effects if players use information signals as coordination devices.

the experimental results can be explained as the existence of "feedback loops" in treatments T1 and T2, and our estimate confirm such hypothesis.

The paper is organised as follows. In Section 1 we describe the theoretical model, the experimental design, and the behavioural hypotheses. In Section 2 we report the main experimental results, with the descriptive analysis of our data set. Section 3 reports the individuals' data analysis, while section 4 concludes.

1. Theory and Experimental Design

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

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

We assume zero unit costs so that the profit function of agents interacting for an exogenously fixed, and known, number of periods was:

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

Assuming competition takes place in 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 benchmark in the case firms move sequentially (with *i* being the first mover and firm *j* being the second mover), the Nash and the collusive equilibria when they move simultaneously.

TABLE 1: Theoretical equilibria points

	P	***π***
Nash-Bertrand simultaneous equilibrium	8	128
Collusive equilibrium	12	172
Sub-game perfect equilibrium (*i*, *j*)	10; 9	130, 144

Legenda: In the case of sub-game equilibrium, following Gal-Or (1985), the theoretical equilibrium prices slightly differ from the reported values. However, given that the prices could take only integer values, the values reported in the table turn out to be higher than the theoretical prices at (10, 9).

The price model reported above constituted the theoretical benchmark on which the experiment was built. Precisely, the experiment was designed as a series of duopolistic markets where each competitor decided a selling price for their product. The first player chose a price, then the second player decided accordingly, and market profits were calculated and reported to subjects at the end of each period. The experiment lasted 10 periods. There were 80 subjects in the experiment, divided in three different sessions,T0 (26 subjects), T1 (26 subjects) and T2 (28 subjects).

Each participant 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 players would be the second mover throughout the entire game. Participants were informed on the values of the demand coefficients and costs, 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.[7]

Our experimental settings were based on several distinguishing aspects, all chosen to enhance the role of information in determining individuals' choices: i) we selected undergraduate, graduate and doctoral students and staff members who had been trained in IO, Management Economics and Game Theory; ii) we implemented the fixed matching protocol; iii) we used a profit calculator, avoiding payoff tables; iv) the market game lasted ten periods (the duration was stated in the Introduction sheet).

Firstly, our initial hypothesis was that a trained pool of subjects was more able to form rational expectations and therefore more able to evaluate information on prices and profits.

Secondly, the fixed matching protocol has been considered the correct setting to test the equilibrium predictions of market models (Holt, 1985).

Thirdly, we designed markets with a short duration (ten periods) and subjects received high rewards for their performance; also, we handled the Instructions at the beginning of the session, but we left time to study them and allowed practice rounds which were aimed at explaining how the computer programme worked.[8]

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[7] The Instructions and the Experimental program in Z-Tree are available on request.

[8] Our subjects' pool was constituted by students who had never participated in a market experiment before, though they were trained in market models. The practice rounds had the only purpose to allow them to get acquainted with the computer programme and the screens. They were aware they were not really playing the game yet, and there were no monetary rewards from these rounds. Subjects were paid in experimental tokens (exchange rate: 1 token=0.10 Euros), according to one period profit, which was randomly decided at the end of the experiment. The experiments were conducted in Siena and Naples, and lasted about one hour per session.

In our hypotheses, the combination of the subjects' training, the short duration of the sessions, the high final stakes and the fixed matching protocol are important elements to enhance the role of information on the choices of the competing players and to provide a valid test of the theory on sub-game perfection in a price game. In addition to that, we use the profit calculator, in order to avoid confusions between tables of observed choices (T2) and theoretical ones.

The central feature of our experiments concerns the design of the information that participants were given during the session and we will describe this aspect in detail.

In T0, after player A had entered her price choice, player B received a message on the screen in which she was told that A had already chosen, and she could now enter her choice. They were after informed on the respective profits they had obtained for that specific market day.[9]

In T1, the B player, before making her decision, received information on her screen on the price chosen by A.

As in T0, at the end of the period, both players could view - on the screen – their profits, however, in this setting, they could also view both market prices.

In T2, at the beginning of the period (starting with the second one), players could call up, at the press of a key, a table in which the prices and the profits in all (*n*-1) markets for all previous periods were reported. However, during the market day, Player B (as in T1) would be informed on A's price choice before deciding and - as in T0 and T1 - both players would be informed on prices and profits in their own market at the end of the period.

T2 allows information sharing and in this setting, it is possible to examine the existence of feedback loops between positive/negative reciprocity and information.

1.2. The behavioural hypotheses and the experimental predictions

The obvious candidate for the hypotheses testing relates to the assumption that subjects will play profit maximizing choices thus converging to the Sub-Game Perfect equilibrium prices (10, 9).

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[9] T0 correspond to a market design with a Positional Order Protocol (POP), in which subjects are aware of the order of the moves even though they do not observe the actual choice. Guth et al.; 1998 provides evidence on these specific types of designs. In fact, though common knowledge of the games' structure should suffice for the emergence of the leadership, the evidence is that in the presence of games with a unique equilibrium, behavior does not change and play converge to the simultaneous values. One possible reason is that POPs' designs are informationally equivalent to simultaneous duopoly experiments, even if players are aware of the sequence of the moves. In POPs, the convergence to simultaneous Nash equilibrium quantities\prices can be intuitively explained by noticing that when followers do not observe the leaders' actions any point on their reaction function can constitute an optimal response.

In fact, in price competition, it can be stated that, under the conditions of quasi-concave profit functions, continuous and increasing reaction functions and identical firms, the following inequalities hold:[10]

$$\pi^F(p^L, p^F) > \pi^F(p^L, p^L) = \pi^L(p^L, p^L) > \pi^L(p^L, p^F) > \pi^L(p^N, p^N) \quad \textbf{(3)}$$

The left hand side of the inequality states that a price duopolist prefers to be a follower rather than a leader, even though he\she prefers to move sequentially rather than acting simultaneously, whichever role is playing (Gal-or, 1985). The basic intuition behind (1) can be summarized in the case of identical firms, by noticing that the leader's price is higher than the price corresponding to the Nash simultaneous value, since his profit, taking into account the follower's optimal response, is increasing in p^N. By the same token, the follower's optimal response, p^F, is smaller than p^L - since the follower's reaction function is flatter than the 45° line - and , as for the leader, higher than p^N.The first hypothesis of our research is based on (1)-and it can be stated as follows:

CLAIM 1: *Optimal Pricing Behaviour: no differences across treatments, individuals' strategies converging to (10, 9) prices*.

CLAIM 2: *Reciprocity and Information: differences across treatments, according to the level of information and the emergence of positive (negative) reciprocity[11].*

In the partial (T1) and in the full information treatment (T2), two main explanations can be accounted for pricing dynamics: 1) the short-term reactions to the co-player in the same market (reciprocity); 2) the short-term effect of learning the best pricing choice across all markets.

We conjecture that if information has a positive effect on coordinating players around the sub-game profit level, then in the full information treatment (T2) reciprocity decreases, prices are stable and individuals' will imitate the best price strategy which can be observed in all markets.

[10] See: Van Damme and Hurkens, 2004; p. 405.

[11] When the choice variable is the product's selling price, negative reciprocity corresponds to declining prices and profits. However, for different choice variables (as Investiment, Advertising etc.) negative reciprocity may correnspond to decreasing profits and increasing values of the choices' variables. It can also be noticed that – according to some authors – negative reciprocity can be brought about by psychological factors, as anger and frustation due to the competitive behaviour of rivals (see Battigalli et al.; 2019).

2. Description of the results: the aggregate statistics

2.1 Average and Median prices

As a preliminary step in the analysis of the experimental evidence, we concentrate our attention on the examination of the average and median prices in the three settings; furthermore, we test the hypothesis underlying Claim 1, that is, prices and profits do not differ in the three contexts. Table 2 reports the average and median prices in the three sessions.

Table 2: Average and Median prices

Treatment	Session	Price First Mover	Price Second Mover	Profit First Mover	Profit Second Mover
Average price	**T0**	**6,41** (1.67)	**6.79** (2.10)	**109.99** (21.90)	**107.55** (21.28)
Median	**T0**	**6**	**6**	**108**	**108**
Average price	**T1**	**8.53** (2.75)	**8.16** (2.27)	**117.75** (25.27)	**128.31** (37.35)
Median	**T1**	**8**	**8**	**120**	**128**
Average price	**T2**	**10.27** (3.20)	**9.34** (3.19)	**115.86** (34.4)	**135.67** (37.80)
Median	**T2**	**10**	**9**	**120**	**136**
Legenda: Average prices are calculated over the ten periods; standard errors in brackets.					

The differences among the three treatments are noticeable.

In T2, the average price is the closest to the sub-game equilibrium price, both for leaders and followers; and median prices correspond to the sub-game values. The followers' profits are the highest in this context and they are significantly higher than the leaders' profits.

In T1 average prices are closer to the Nash simultaneous equilibrium value than to the sub-game equilibrium point, and median prices are precisely correspondent to the simultaneous value. However, there is a difference in observed players' prices and profits for leaders and followers, and the followers still enjoy a strategic advantage over the leaders.

The evidence in T0 differs both from T1 and T2, in as much as i) prices and profits are the lowest compared to the alternative contexts; ii) the followers do not gain more than leaders (the followers' average price, on the contrary, is higher than the leaders' average price); iii) the average and median prices are well below the simultaneous Nash value of (8,8) reported in Table 1.

In Table 1A (in Appendix) we test for differences among the three settings, using several statistical procedures illustrated in the *Notes*. We perform tests *within* treatments (first part of the Table) and *across* treatments (second part of the Table). As it is evident, these tests support evidence in Table 2.

Let's describe key patterns via data visualization. Hence, Figures 1-4 show first and second movers' prices in the first 2 treatments. In T0, prices quickly converge well below the simultaneous Nash values, confirming the absence of any strategic behaviour. In T1, the situation radically changes since the information about the opposed players favours the shift towards higher prices in many cases.

Fig. 1-First movers 'prices T0

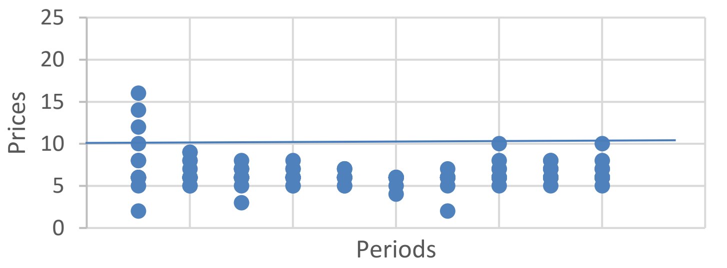


Fig. 2-First movers' prices- T1

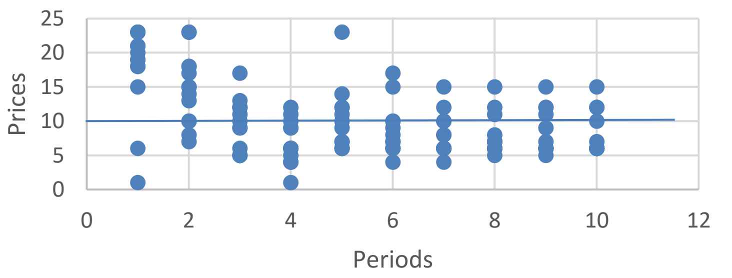
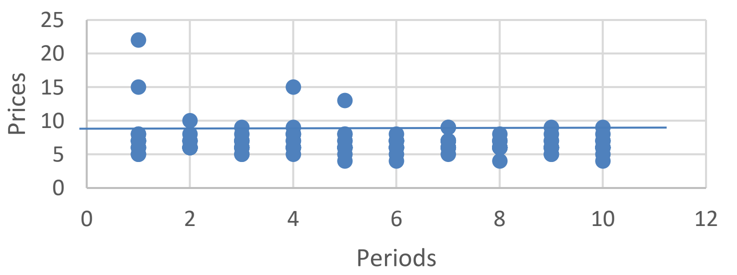
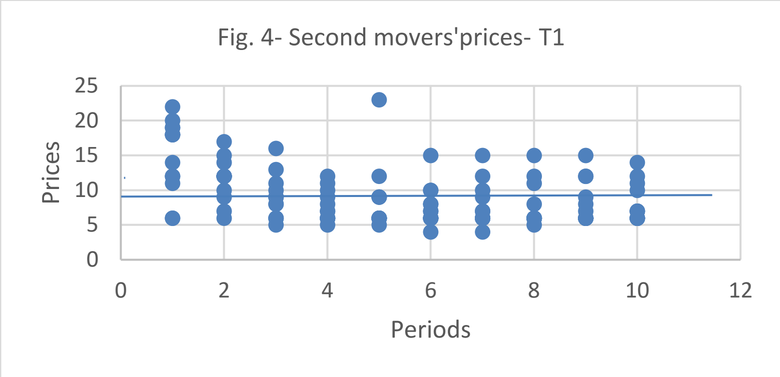
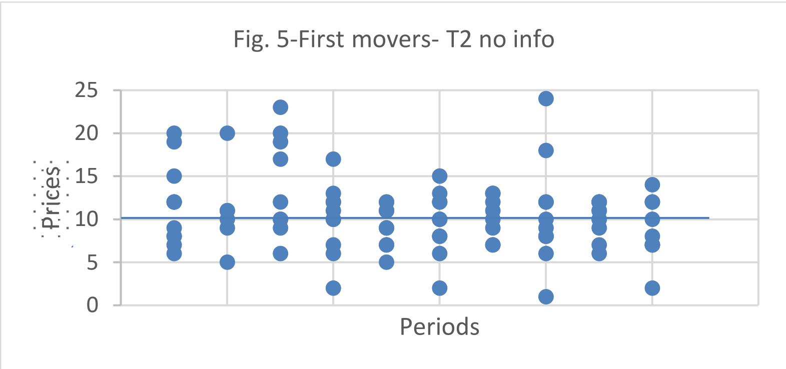


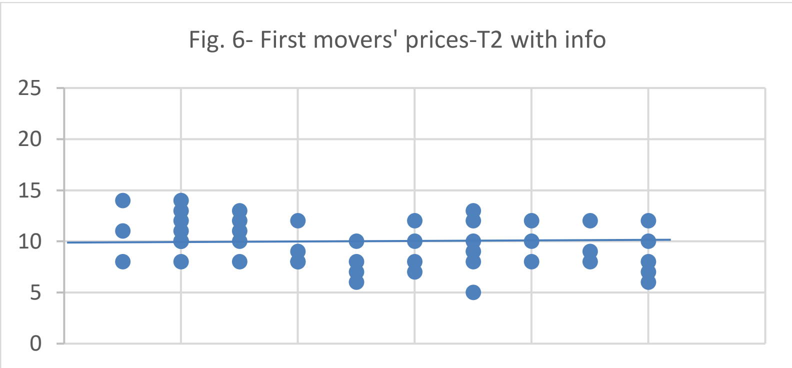
Fig. 3- Second movers'prices-T0

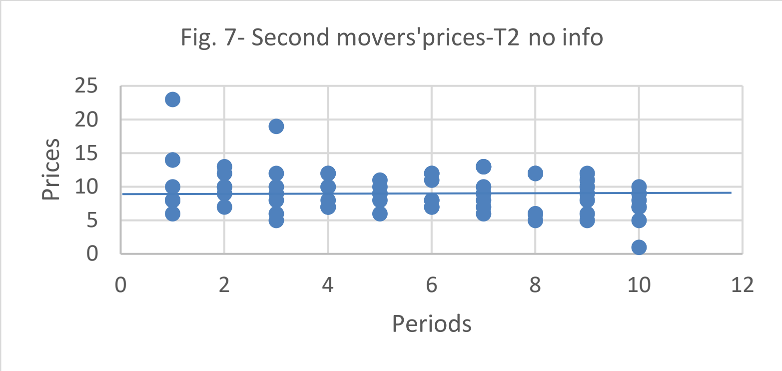


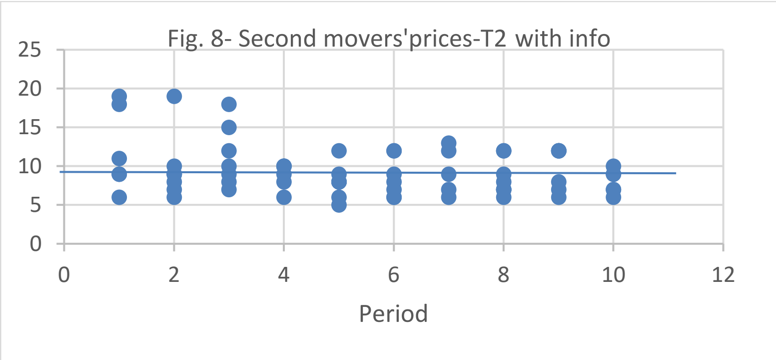


Figures 5-8 show main patterns in the T2 treatment, without (0) and with (1) information on the other markets . The impact of the additional information is revealed by a faster convergence towards the collusive equilibrium in the case of the first movers. Second movers appear to be less affected, most likely as a result of their informational advantages.









Overall, the descriptive evidence suggests that information on the competitors' strategies affects the behavior of subjects in a price sequential game. When the follower does not observe the leader's actions, the strategic advantage disappears. By the same token, when the follower observes the leader's choice we find that – though there a competitive advantage – prices and profits do not – on average – correspond to the sub-game level. Finally, we find significant distances between T1 and T2 in the sense that prices and profits are higher (significantly) in T2 than in T1.

2.2 Convergence

In the following, we focus on the forces driving first and second movers' behavior. There are several non-mutually exclusive possibilities. In addition to the profit maximizing motive which appears to be present for both first and second movers, another obvious possibility is that players respond to (un-)kindness with (un-)kindness – positive (negative) reciprocity with positive (negative) reciprocity; a further potential motivator is provided by Learning Direction Theory. In contrast to the other possible motivations, LDT provides also a basis for explaining why behavior and outcomes are so different in T2.

LDT suggests two possible adjustment rules:

Rule a: I adjust my price upwards (downwards) if in the previous period I would have earned more having a higher (lower) price; and,

Rule b: I adjust my price upwards (downwards) if in the previous period players in other markets others earned more than me having a higher (lower) price.

Rule a is applicable to first movers in all the treatments (and for second movers in T0)[12], whilst rule b is applicable to both first and second movers but only for T2 and thus provides a possible basis for distinguishing this treatment.

In order to take the analysis one stage further, it makes sense to put the various considerations discussed thus far in a regression framework. As confirmation of the earlier discussion we first estimated (myopic) best reply equations for (first and) second movers of the form:

$$p_{it}^{fm} = \alpha + \beta p_{it-1}^{sm} + \omega_i + \varepsilon_{it} \qquad (2a)$$

for first movers, and,

$$p_{it}^{sm} = \alpha + \beta p_{it}^{fm} + \omega_i + \varepsilon_{it} \qquad (2b)$$

for second movers, in both cases using random effects GLS with AR(1) errors.

It is important to remember that players in T0 view both their own and their opponent's profit from the prior period. As a result, they could only argue the opponent's pricing and adjusting their own price upward or downward based on whether they would have made more money in the prior period with a higher or lower price.

Results for treatment T2 are reported for the whole sample and then separately for cases in which information on other players was requested.

Points to note on these estimations are:

- In T0 there is practically no response to price – in fact, in this treatment, prices converged very quickly to the competitive equilibrium. Consequently, also the R^2 value is very low for both first and second movers in T0.

[12]Obviously, second movers in T1 and T2, having observed the price of first movers, should already know the profit maximizing option (from the profit calculator) before they choose their price and so the rule is superfluous for them.

- For first movers in T1 and second movers in T1 and T2 (with or without additional information) the coefficient on the other players price is statistically significant (often at p < .01).
- In T2, more information about the other markets eliminates first movers' response to the price of the second mover in the previous period.
- As regards the goodness-of-fit, this is much better, as a whole, for second movers as one might expect given the certainty attaching to the first movers choice.

Table 3: Estimation of best response models for first and second movers

First movers										
	T0		**T1**		**T2 (pooled)**		**T2 (no information)**		**T2 (With information)**	
	coeff	**s.e.**	**coeff**	**s.e.**	**coeff**	**s.e.**	**coeff**	**s.e.**	**coeff**	**s.e.**
p_{it-1}^{sm}	0.10**	0.04	*0.60****	0.08	*0.44****	0.10	*0.62****	0.13	*0.15*	0.11
Intercept	*5.58****	0.33	*3.59****	0.78	*5.88****	0.97	*4.43****	1.34	*8.29****	3.23
N	117		117		126		84		42	
R2	0.04		0.35		0.19		0.24		0.13	
Second movers										
	T0		**T1**		**T2**		**T2 (no information)**		**T2 (with information)**	
	coeff	**s.e.**	**coeff**	**s.e.**	**coeff**	**s.e.**	**coeff**	**s.e.**	**coeff**	**s.e.**
p_{it}^{fm}	0.06	0.08	*0.62****	0.03	*0.48****	0.06	*0.48****	0.07	*0.43****	0.09
Intercept	*6.19****	0.57	*3.00****	0.43	*4.39****	0.65	*4.15****	0.86	*5.21****	1.03
	117		130		140		78		62	
	0.01		0.78		0.46		0.63		0.32	

Notes: 1) Models estimated using GLS with random individual effects and AR (1) errors.
2) Statistical significance indicated as follows:* indicates p < 0.10, ** indicates p < 0.05 and *** indicates p < 0.01.

These results go some way towards confirming the descriptive analysis reported above, and in particular, they show a clear distinction between play in T0 on the one hand and T1 and T2 on the other, however, they do not tell us much about what is actually motivating behavior. In particular, they do not tell us a great deal about what is driving the differences in behavior between T1 and T2 which, in the standard theoretical model should not differ. In order to delve deeper into this aspect, considerations concerning reciprocity (and punishment) and LDT were introduced explicitly into the regression framework. In this case the variation in the price choices are estimated including, as explanatory variables, factors representing reciprocity (and punishment) and the two LDT rules (as appropriate). Specifically , the following ‘error correction’ models were estimated:

$$p_{it}^{fm} - p_{it-1}^{fm} = \alpha + \beta(p_{it-1}^{fm} - p_{it-1}^{BA}) + \gamma_1(p_{it-1}^{sm} - p_{it-1}^{fm})^{+} + \gamma_2(p_{it-1}^{sm} - p_{it-1}^{fm})^{-} + \omega_i + \varepsilon_{it} \quad (3a)$$

for first movers in T1,

$$p_{it}^{fm} - p_{it-1}^{fm} = \alpha + \beta(p_{it-1}^{fm} - p_{it-1}^{BA}) + \gamma_1(p_{it-1}^{sm} - p_{it-1}^{fm})^{+} + \gamma_2(p_{it-1}^{sm} - p_{it-1}^{fm})^{-} + \partial(p_{it-1}^{fm} - p_{t-1}^{max\pi sm}) + \omega_i + \varepsilon_{it} \quad (3b)$$

for first movers in T2 who gained additional information on the other markets,

$$p_{it}^{sm} - p_{it-1}^{sm} = \alpha + \beta(p_{it}^{fm} - p_{it-1}^{BA}) + \gamma_1(p_{it}^{fm} - p_{it-1}^{sm})^{+} + \gamma_2(p_{it}^{fm} - p_{it-1}^{sm})^{-} + \omega_i + \varepsilon_{it} \quad (3c)$$

for second movers in T1, and,

$$p_{it}^{sm} - p_{it-1}^{sm} = \alpha + \beta(p_{it}^{fm} - p_{it-1}^{fm}) + \gamma_1(p_{it}^{fm} - p_{it-1}^{sm})^{+} + \gamma_2(p_{it}^{fm} - p_{it-1}^{sm})^{-} + \partial(p_{it-1}^{fm} - p_{t-1}^{max\pi sm}) + \omega_i + \varepsilon_{it} \quad (3d)$$

for second movers in T2 who gained additional information on the other markets.

Thus, in the first mover equations, (3a) and (3b), the change in price is determined by:

a) a term representing the distance of the FM's previous price from that which would have – given the reply of the SM – maximized her profits (LDT rule a);
b) two terms representing the previous period's behaviour of the SM defined as the distance of the SM's price from the first mover's – here, as in Guth et al. (2006)- two coefficients are estimated to allow different reactions of FM's to whether the SM's behaviour was accommodating/positively reciprocal($p^{sm}>p^{fm}$) or aggressive/negatively reciprocal($p^{sm}<p^{fm}$); and, for T2,
c) the distance of the FM's price from the price which received the maximum profits in all the markets in the previous round (LDT rule b).

For second movers, analogous equations were estimated, (3c) and (3d), however in this case:

a) the LDT rule a – which has no sense for the second mover, is replaced by the dynamic counterpart of the best reply rule – given by the variation in the FM's price between this and the previous period;
b) positive and negative reciprocity are measured in terms of the difference between the FM's price in this period and the SM's price in the previous period; and,
c) the final term is exactly analogous to the fourth term in the FM equations, applying in this case the SM (LDT rule b).

Table 4: Estimation of dynamic models of first mover behaviour

First movers		**T1**	**T2 Pooled**	**T2 With info**
		I Coeff. (Std. Err.)	**II (Coeff. Std. Err.)**	**IV (Coeff. Std. Err.)**
LDT rule a	$(p_{it-1}^{fm} - p_{it-1}^{BA})$	-0.45***(0.09)	-0.53***(0.12)	0.056(0.69)
Positive Reciprocity	$(p_{it-1}^{sm} - p_{it-1}^{fm})^{+}$	1.76***(0.42)	-0.06(0.19)	-0.112(0.237)
Negative Reciprocity	$(p_{it-1}^{sm} - p_{it-1}^{fm})^{-}$	0.69***(0.17)	0.56**(0.19)	0.458*(0.269)
LDT rule b	$(p_{it-1}^{fm} - p_{t-1}^{max\pi fm})$			-0.868*(0.54)
constant		0.105(0.352)	1.41***(0.38)	-1.114(2.01)
n		117	126	42
R²		0.60	0.40	0.59
Notes: 1) Models estimated using GLS with random individual effects and AR(1) errors; 2) In all cases, statistical significance is indicated as follows: * indicates p < 0.10, ** indicates p < 0.05 and *** indicates p < 0.01.				

Table 5: Estimation of dynamic models of second mover behaviour

Second movers		**T1**	**T2 Pooled**	**T2 With info**
		I Coeff. (Std. Err.)	**II (Coeff. Std. Err.)**	**IV (Coeff. Std. Err.)**
LDT rule a	$(p_{it}^{fm} - p_{it-1}^{fm})$	0.11*(0.06)	-0.09(0.06)	0.035(0.08)
Positive Reciprocity	$(p_{it}^{fm} - p_{it-1}^{sm})^{+}$	0.35***(0.10)	0.628***(0.104)	0.41***(0.129)
Negative Reciprocity	$(p_{it}^{fm} - p_{it-1}^{sm})^{-}$	0.85***(0.10)	0.763**(0.09)	0.613***(0.125)
LDT rule b	$(p_{it-1}^{sm} - p_{t-1}^{max\pi sm})$			-0.34***(0.07)
constant		-0.08(0.22)	-0.76**(0.255)	-1.201(0.329)
n		117	126	62

R^2		0.60	0.57	0.73
Notes: 1) Models estimated using GLS with random individual effects and AR(1) errors; 2) In all cases, statistical significance is indicated as follows: * indicates p < 0.10, ** indicates p < 0.05 and *** indicates p < 0.01.				

The results of the estimation suggest that there are significant differences in the responses of players both by type of player and by treatment. One may also observe that – especially because the equation is differenced - the goodness of fit is relatively high, for both first and second movers, particularly for T1.

The LDT rule “a” is a strong predictor of behaviour for first movers in T1 and T2 (with no additional information). On the other hand, first movers’ negative reciprocity decreases in importance moving from T1 to T2 (with additional information) while the LDT rule b matters at ten percent level.

Second movers do not seem to react strongly to movements in the first movers’ prices per se, but they do react, in both T1 and T2, to both positive and negative reciprocity in FM play. In T2, the effect of the LDT rule b is clearly statistically significant while reciprocity decreases.

Conclusions

This paper has contributed to the debate on the role of information in markets in several ways. First, it has confirmed the game-theoretic predictions and the previous findings of, in particular, Kubler and Müller (2002) regarding the first mover disadvantage in Bertrand sequential markets and the significantly higher prices and profits of both players in sequential as compared to simultaneous markets. Second, the paper went beyond previous studies in considering the effects of the availability of information on player outcomes in markets unconnected to the one in which players operate. In this case, the standard game theory predictions are that there should be no difference between the treatments (T1 and T2). However, here too a clear statistically significant impact on outcomes was found with information leading to increased prices and profits.

The paper then sought to identify the factors which were underlying players behaviour which were leading to these outcomes. In the first place, descriptive analysis showed that the provision of additional (non-strategic) information on other markets was associated with both more collusion and more profit maximizing behaviour in T2 as compared with treatment T1 where only ‘strategic’ information was provided.

A dynamic econometric model of players’ choices supported the notion that Learning Direction Theory was playing an important role. The provision of additional information eliminates first movers' response to previous miscalculations (LDT rule a), whilst emulation of more successful players in other markets (LDT rule b) plays an important role, in particular for second movers; a role which was supported also by a large reaction in T2 to first movers’ positive reciprocity, thereby supporting the move towards more collusive markets. Overall, reciprocity can explain the results, but full information reduces reciprocating strategies.

Thus, it appears to be the interaction between reciprocity and the emulation of more successful players which is driving the move towards higher profits and less competitive markets when information on rivals is provided.

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Appendix 1

Table 1A: Hypothesis tests on prices and profits

Hypotheses	**T0**	**T1**	**T2**
H_0: pfm = psm **H_a: pfm>psm**	-	**	**
H_0: πfm = πsm **H_a: πfm <πsm**	-	**	***
	T0 VS T1	**T0 VS T2**	**T1 VS T2**
H_0: $pfmT_i = pfmT_j$ **H_a: $pfmT_i<pfmT_j$**	***	***	**
H_0: $psmT_i = psmT_j$ **H_a: $psmT_i<psmT_j$**	-	***	**
H_0: $pT_i = pT_j$ **H_a: $pT_i<pT_j$**	**	***	***
H_0: $\pi fmT_i = \pi fmT_j$ **H_a: $\pi fmT_i<\pi fmT_j$**	-	**	*
H_0: $\pi smT_i = \pi smT_j$ **H_a: $\pi smT_i<\pi smT_j$**	***	***	***
H_0: $\pi T_i = \pi T_j$ **H_a: $\pi T_i<\pi T_j$**	**	***	***

Notes: 1) For within treatment tests, the Wilcoxon signed rank test is used; for between treatment tests where independence across players may be assumed, the Mann-Whitney test is applied.
2) In the within treatment tests, for T0, two-tailed tests are used, for T1 and T2, one-tailed tests are employed, given nature of the test and a priori expectations.
3) Statistical significance indicated as follows: - indicates $p \geq 0.10$, * indicates $p < 0.10$, ** indicates $p < 0.05$ and *** indicates $p < 0.01$.