Research Proposal:

An Experimental Investigation of Product Differentiation and Price Competition in the Presence of Network Effects*

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Abstract

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1 Introduction

This proposed research project deals with oligopoly under network effects. Such a situation was demonstrated by Becker (1991, p.1109): “A popular seafood restaurant in Palo Alto, California, does not take reservations, and every day it has long queues for tables during prime hours. Almost directly across the street is another seafood restaurant with comparable food, slightly higher prices, and similar service and other amenities. Yet this restaurant has many empty seats most of the time.” In this example consumers have satisfaction from eating in a popular place where many others are eating. In other words, the market demand is not determined solely by the prices of the food but also by the size of the group entering one restaurant or another (i.e., aggregate demands).

Inspired by this case, de Almeida Prado et al. (2011) and de Almeida Prado (2013) developed a model where they suggest that the polarization of demands discussed for example by Becker (1991) is a consequence of the proximity of restaurants which in its turn follows from strong network effects on consumers’ decisions. The explanation for such a behavior goes as follows: when firms do not differentiate products, the only factors determining individual choices are differences in aggregate demands. In this case, network effects lead to herd behavior and a polarization of demand is expected to happen. Further result of the model is that the market leader (i.e., the firm with the largest market share) can take advantage of its position and charge a higher price than it’s markets follower while still maintaining to keep all their consumers (this is also consistent with Mitchell and Skrzypacz, 2006). If the network effect is sufficiently strong, the market leader’s price turn to be much higher than the equilibrium price, which is predicted in case where players separate and share the market symmetrically. Since each firm is equally likely to become the market leader, their expected profits may be higher when they agglomerate and fight for the market leadership rather than separate and share the market symmetrically. Conversely, firms tend to separate and engage in a standard
Hotelling price competition when their network effects are sufficiently weak. That may explain the agglomeration of firms where consumers put high value in socializing with other consumers (e.g., bars, restaurants, night clubs); and the dispersion of firms in which consumers are primarily interested in accessing the product (e.g., drug stores, bakeries).

It is very difficult to find situations in the business world that corresponds exactly to the theoretical model. Even in the restaurant case that inspired the research some of the assumptions may not be varied or fulfilled. In this respect, laboratory experiments allow to specify an environment and define the institutions to be used. Thus, they provide an opportunity to test descriptiveness of models even under “strong” theoretical assumptions that are hardly observed in the business world. It is, therefore, hardly surprising that models of oligopoly were among the first experiments conducted in economics (e.g., Sauermann and Selten, 1959; Hoggatt, 1959; Fouraker and Siegel, 1963).

The aim of this research project is to test the prediction of price completion models in the presence of network effects (see Cabral, 2011 for a review) as well the location/price-setting model by de Almeida Prado (2013). Moreover, there are several additional reasons why we want to investigate location- and price-setting dynamics under network effects: First, although price competition is an issue of major interest in economics and has been subject to large experimental research (see, for example, Engel, 2007 and Potters and Suetens, 2013), there is very limited experimental evidence on price competition under network effects or demand inertia (Keser, 1993, 2000; Bayer and Chan, 2007). We plan to complement the previous work by (i) testing the isolated effect of network on firms’ collusion, and also (ii) the impact of non binding communication between the firms on collusion. Second, previous experimental findings are not in line with equilibrium predictions, and the results by Bayer and Chan (2007) are qualitatively different from Keser (2000). However, results from a pre-test experiment that we have recently conducted (see section 5) indicate that our results are much closer to the theoretical prediction than
previous studies. Thus, our contribution may be especially important as it may shed light on topic with ambiguous evidence and also show that theory may be good predictor of behavior even under competition with network effect (or demand inertia). Third, we introduced a computational tool that may be especially suitable in such experiments where optimal pricing strategy could vary over time. Thus, we intend to contribute methodologically to the design of further experiment on network externalities. Finally, we intend to contribute to the literature by being the first to test the effect of network (or demand inertia) in a location-setting model.

The paper is organized as follows: In Section 2 we describe the theoretical location-price model with network effect that is the basis for our experimental investigation. In Section 3 we describe the previous related literature. In Section 4 we portray the proposed experimental design, and Section 5 presents results from a pre-test conducted in September 2013.

2 Theoretical Model

This section portrays the theoretical model and results by de Almeida Prado (2013) to be tested experimentally. We introduce a location-price game between two firms (e.g., restaurants), which compete for socially interacting consumers distributed along a measurable spatial space (conveniently, a circle of circumference 1). The firms differentiate their products as they choose their geographic locations along the address space of consumers. Consumers decide simultaneously on the firm they consume from according to a Hotelling-type utility function, in which individual utility increases in the number of consumers of the firm under consideration. In equilibrium the distance between firms depends on the strength of positive network effect in consumers’ decisions and on the transportation costs of consumers. Assuming quadratic transportation costs as in D’ As-
premont et al. (1979), we derive the following results. On the one hand, if the strength of network effect among consumers is larger than a critical value, then the distance between firms is zero. On the other hand, if it is lower than this critical value, then the distance between firms is maximal in Nash equilibrium. The latter corresponds to the standard result of D’Aspremont et al. (1979), who does not assume social interactions among consumers.

2.1 Model

Consumers’ interactions. We consider a model in which consumers are uniformly distributed along a circular address space\(^1\) \(N\) of circumference 1. There are two firms, 1 and 2, located at circle points \(l^{(1)}\) and \(l^{(2)}\). Both firms sell the same physical good. As in d’Appremont et al. (1979) we assume that transportation costs are quadratic, i.e., a consumer living at \(x \in N\) incurs a quadratic transportation cost \(\nu d^2(x, l^{(i)})\) to go to firm \(i\) (\(i \in \{1, 2\}\)), where \(\nu\) is a positive model parameter, and \(d(x, l^{(i)})\) denotes the shortest distance between \(x\) and \(l^{(i)}\) along the circle.

For simplicity in exposition we assume that each consumer purchases one unit of the good either from firm 1 or firm 2. We denote by \(N^{(i)}\) the set of consumers that buy the good from firm \(i \in \{1, 2\}\). Since \(N = N^{(1)} \cup N^{(2)}\), \(N^{(1)}\) describes the configuration of consumers’ decisions.

We now assume that consumers’ \(x\) gross utility from consumption depends on other consumers’ decisions. If \(x\) buys the good from firm \(i\), then \(x\)’s gross utility is

\[
J|N^{(i)}| \quad (i \in \{1, 2\}) \tag{1}
\]

\(^1\)Circular address spaces, originally due to Salop (1979), are very common in the literature (Novshek (1980), Eaton and Wooders (1985), Kats (1995), Pal (1998) and Gupta et. all (2006)). We choose a circular address space for simplicity in exposition. Analogous results can be derived by considering the interval \([0, 1]\).
where $J$ is a positive parameter, and $|N^{(i)}|$ denotes the normalized one-dimensional Lebesgue measure of $N^{(i)}$ along the circle, where we suppose that $N^{(i)}, i \in \{1, 2\}$ are Lebesgue measurable subsets of $N$. (If $N^{(i)}$ is path connected, then $N^{(i)}$ is an arc on the circle $N$, and $|N^{(i)}|$ is the length of the arc divided by the total circumference $2D_{\text{max}}$).

If consumer $x$ chooses firm $i \in \{1, 2\}$, his/her net utility is

$$U^{(x)}(i, |N^{(i)}|) = J|N^{(i)}| - P^{(i)} - \nu \left[d(x, l^{(i)})\right]^2$$

(2)

where $P^{(i)}$ denotes the price charged by firm $i$.

We introduce below a location-price game of firms under positive externalities of consumers, that is, under $J > 0$. Although consumers’ utility depends on other consumers decisions, it is worth stressing that only the firms 1 and 2 are players of the location-price game. Consumers just react simultaneously to prices and other consumers’ decisions in accordance to (2).

Each firm’s $i$ strategy is composed by an initial location $l^{(i)}$, which is chosen at time $t = 0$, and a sequence of non-negative prices, which are played on the subsequent times $t = 1, 2, \ldots$. Each price at time $t$, denoted by $P^{(i)}_t \ (i = 1, 2)$ is a function of the game history $H_t$ (defined below).

The payoff of firm $i$, denoted by $\Pi^{(i)}\left((l^{(1)}, P^{(1)}); (l^{(2)}, P^{(2)})\right)$, is the expected average profit over time, where the firm costs are zero:

$$\Pi^{(i)}\left((l^{(1)}, P^{(1)}); (l^{(2)}, P^{(2)})\right) = \mathbb{E}(\pi^{(i)}), \quad \pi^{(i)} = \lim_{T \to \infty} \frac{1}{T} \sum_{t=1}^{T} |N^{(i)}_t| \cdot P^{(i)}_t \ (i = 1, 2) \quad (3)$$

Above, $\mathbb{E}$ denotes the mathematical expectation operator, and $N^{(1)}_t$ and $N^{(2)}_t$ denote the sets of consumers that choose firms 1 and 2 at time $t$, respectively.

The game history $H_t$ available for both players to choose their prices $P^{(1)}_t$ and $P^{(2)}_t$ at time $t = 1, 2, \ldots$, is
where \( l = (l^{(1)}, l^{(2)}) \), \( P_t = (P_{t}^{(1)}, P_{t}^{(2)}) \) and \( N_t = (N_t^{(1)}, N_t^{(2)}) \).

In order to specify completely the payoff functions \( \Pi^{(i)} \), we define below how consumers decisions (determined by sets \( N_t^{(1)} \) and \( N_t^{(2)} \)) evolve in time.

**Dynamics of consumers’ decisions.** First of all, we assume that \((|N_0^{(1)}|, |N_0^{(2)}|)\) is random. More specifically, we assume that \(|N_0^{(1)}|\) is uniformly distributed over the interval \([0, 1]\) and \(|N_0^{(2)}| = 1 - |N_0^{(1)}|\).

The vector \((|N_0^{(1)}|, |N_0^{(2)}|)\) stands for the consumers initial expectation about the real demand to be formed at time \( t = 1 \). This initial market share (expectation) is not observed by the two players (the firms) when they choose their initial prices \( P_1^{(i)}, i = 1, 2 \).

For \( t = 1, 2, \ldots \), we assume that consumers are “myopic” rather than fully rational in the sense that they choose simultaneously best individual responses to other consumers’ expected decisions \( E(|N_t^{(1)}|) \) and \( E(|N_t^{(2)}|) \) (where \(|N_t^{(1)}|\) and \(|N_t^{(2)}|\) are not observed by the consumers at time \( t \)) and the observed prices \( P_1^{(1)}, P_2^{(2)} \). As a simple rule of common expectation, we assume that \( E(|N_t^{(1)}|), E(|N_t^{(2)}|) = (|N_{t-1}^{(1)}|, |N_{t-1}^{(2)}|) \).

Let us denote by \( i_t^{(x)}(\in \{1, 2\}) \) the decision of consumer \( x \) at time \( t \geq 1 \). In light of the consumers’ utility function (2), we set \( i_t^{(x)} = \arg \max_{i \in \{1,2\}} U_t^{(x)}(i, |N_{t-1}^{(i)}|) \), where

\[
U_t^{(x)}(i, |N_{t-1}^{(i)}|) = J|N_{t-1}^{(i)}| - P_t^{(i)} - \nu \left[ d(x, l^{(i)}) \right]^2
\]  

It is straightforward to show recursively that \( N_t^{(i)}, i = 1, 2, t = 1, 2, \ldots \) are Lebesgue measurable sets. Indeed, the numbers \(|N_0^{(1)}|, |N_0^{(2)}|\) are well defined. Now, once we have

\[2\text{When } \arg \max_{i \in \{1,2\}} U_t^{(x)}(i, |N_{t-1}^{(i)}|) \text{ is multivalued, we set } i_t^{(x)} = 1 \text{ without loss of generality.} \]
that $|N_t^{(1)}|$ and $|N_t^{(2)}|$ are well defined, it is easy to see that $N_t^{(i)} = \{ x \mid i^{(x)} = i \}$ is an arc on the circle $N$, and thus Lebesgue measurable ($i = 1, 2$). Since $|N_t^{(1)}| + |N_t^{(2)}| = 1$, the dynamics of $|N_t^{(1)}|$ and $|N_t^{(2)}|$ are uniquely determined by that of $m_t \triangleq |N_t^{(1)}| - |N_t^{(2)}|$. **Dynamics of $(m_t)$**. Let $D$ be the distance between firms on the address space of consumers. Taking into account that the consumers are uniformly distributed over the circle $N$, a straightforward calculation shows that

$$m_t = \psi(m_{t-1}, h_t), \quad \text{where } \psi(m, h) = \begin{cases} 
-1, & \text{if } m \leq \frac{h-\delta}{f}, \\
\frac{d}{\delta}m - \frac{h}{\delta}, & \text{if } \frac{h-\delta}{f} < m < \frac{h+\delta}{f}, \\
1, & \text{if } m \geq \frac{h+\delta}{f},
\end{cases} \quad (6)$$

and

$$h_t = P_t^{(1)} - P_t^{(2)} \quad \text{and } \quad \delta = \nu D(1 - D) \text{ with } 0 \leq D \leq 1/2. \quad (7)$$

**Remark.** Since $|N_t^{(1)}| = (1 + m_t)/2$, $|N_t^{(2)}| = (1 - m_t)/2$ for $t > 0$, equations (3), (4), (6), and (7) defines the game. These equations could be used to test the model for finite time horizon $T$.

### 2.2 Results

Below we present some Nash equilibria of the price competition that occurs after location are fixed. We also solved the overall game applying a backward induction on the location of firms based on the presented outcomes of the price competition. Under some technical conditions, the presented outcomes of the price subgame is unique. These

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3Since $N$ (the address space of consumers) is a circle of circumference 1, $D$ is the shortest arc between the firm locations in $N$, where $0 \leq D \leq 1/2$. 
conditions essentially ensures that players play a convergent price sequence and stop monitoring the game history after some strategic time.

### 2.2.1 Nash equilibria of the price competition

Let us assume that the firms have already fixed their locations along the circle. The proposition below presents a set of Nash equilibria, of which limit prices and payoffs are uniquely determined by the distance between firms.

**Proposition 1.** Let \( \delta = \nu D(1 - D) \), where \( D \) denotes the minimal distance between firms along the circle. Let us consider the price game of firms 1 and 2 with payoff functions \( \Pi^{(i)}((l^{(1)}, P^{(1)}); (l^{(2)}, P^{(2)})), i = 1, 2, \) defined in (3). The price game (for fixed firm locations \( l^{(1)} \) and \( l^{(2)} \)) always has a Nash equilibrium.

Moreover, if \( (P^{(1)}, P^{(2)}) \) is a Nash equilibrium of the price subgame and \( |N_t^{(i)}| \) and \( \Pi_t^{(i)} \) are the values of \( |N_t^{(i)}| \) and \( \Pi_t^{(i)} \) in \( (P^{(1)}, P^{(2)}) \), then the following conditions hold:

**Duopoly equilibrium** If \( 0 < J < \delta \), then the following three conditions are satisfied:

1. The firms play the same long run price, and it is

   \[
   \lim_{t \to \infty} P_t^{(i)} = \delta - J, \quad i = 1, 2
   \]  

2. The market is shared symmetrically in the long run, i.e.,

   \[
   \lim_{t \to \infty} |N_t^{(i)}| = 1/2, \quad i = 1, 2
   \]

3. Both players receive the same payoff, i.e.,

   \[
   \Pi^{(i)} = (\delta - J)/2, \quad i = 1, 2
   \]
(Monopoly equilibrium) If \(0 \leq \delta \leq J\), then the following conditions are satisfied:

1. Firms play the minimum price to attract demand. As soon as one firm monopolizes the market, it increases its price up to \(J - \delta\):

\[
P^{(i)}_{t-1} = \begin{cases} 
0 & \text{if } |N^{(i)}_t| < 1 \\
J - \delta & \text{if } |N^{(i)}_{t-1}| = 1
\end{cases}
\] (11)

2. If \([0 \leq \delta < J]\) then

\[
\text{Prob}\left(\lim_{t \to \infty} |N^{(i)}_t| = 1\right) = \frac{1}{2}, \quad i \in \{1, 2\}
\] (12)

(Each player polarizes the market with probability \(\frac{1}{2}\)).

3. Both players receive the same (expected) payoff

\[
\Pi^{(i)} = (J - \delta)/2, \quad i = 1, 2
\] (13)

where (13) follows immediately from (11) and (12).

2.2.2 Backward induction on the distance between firms

We now solve the overall game by applying a backward induction on \(\delta\), which is an increasing function of the distance between firms \(D\). (The bijection between \(D\) and \(\delta\) is presented in equation (7)). Taking into account Equations (10) and (13), the payoffs of players (as a function of \(\delta\)) is \(\Pi^{(i)}(\delta) = |J - \delta|/2\) for \(0 \leq \delta \leq \delta_{\text{max}}\), where \(\delta_{\text{max}} = \nu/4\) and \(|J - \delta|\) denotes the absolute value \(J - \delta\). Maximizing \(\Pi^{(i)}(\delta)\) yields the equilibrium values of \(\delta\) (and \(D\)). The next proposition present the overall solution of the game.
Proposition 2. Set $\delta_{\text{max}} = \nu/4$. Let $(l^{(1)}, P^{(1)}); (l^{(2)}, P^{(2)})$ be a Nash equilibrium of the location-price game with payoff functions (3). Let $\delta$ depend on the distance between locations $l^{(1)}$ and $l^{(2)}$ as defined in (7)). Then $\delta \in \Delta(J)$, where

$$\Delta(J) = \begin{cases} 
\{\delta_{\text{max}}\} & \text{if } J < \frac{\delta_{\text{max}}}{2} \\
\{\delta_{\text{max}}, 0\} & \text{if } J = \frac{\delta_{\text{max}}}{2} \\
\{0\} & \text{if } J > \frac{\delta_{\text{max}}}{2}
\end{cases} \quad (14)$$

Moreover, the price sequences produced by the interaction of price strategies $P^{(1)}$ and $P^{(2)}$ satisfy the the conditions of Proposition 1 for $\delta = \delta$.

Proposition 2 indicates that the distance between firms is maximal or minimal depending on whether the network effect is sufficiently weak ($J < \frac{\delta_{\text{max}}}{2}$) or sufficiently strong ($J > \frac{\delta_{\text{max}}}{2}$), in which cases, in price subgame, a duopoly or a monopoly equilibrium takes place, respectively. If the network effect is intermediary ($J = \frac{\delta_{\text{max}}}{2}$), then both distances may take place (maximal and minimal), and duopoly or monopoly equilibria will take place, depending on whether firms are far or close from each other.

3 Related Experimental Literature

The proposed project is related to two strands of experimental literature: oligopoly engaging in (i) price competition, and (ii) spatial (location-setting) competition. In such experiments network effects were models so far in the form of demand inertia which "refers to a dynamic relationship between present and past sales" (Keser, 1993, p.134). Moreover, the behavior of oligopolies under demand inertia was investigated only in price-
setting, but not in a location-setting contexts. Finally, although the effect of non-binding communication between firms on collusion have received attention in the literature, the effect of such communication on oligopolies with network effects (or demand inertia) was not yet investigated. In the following we provide a short review of the related experimental literature.

3.1 Price competition experiments

During the years numerous price competition experiments have been conducted. The survey and meta-analysis by Potters and Suetens (2013) and Engel (2007) indicate that in these experiments prices are usually above the Nash equilibrium (i.e., marginal cost). In a recent study Fonseca and Normann (2012) find strong evidence that non binding communication (using a chat window) helps to obtain higher profits for any number of firms, however, the gain from communicating is non-monotonic in the number of firms, with medium-sized industries (four and six firms) having the largest additional profit from talking. The authors also find that firms continue to collude successfully after communication is disabled.

As of today we know of only three experimental papers on price setting oligopoly with network effects (by Keser, 1993, 2000 and Bayer and Chan, 2007). These studies aim at testing the oligopoly model with demand inertia introduced by Selten (1965). Keser (1993) conducted an experiment with asymmetric duopolies (i.e. differing in their constant marginal cost per unit of production). The market demand depends on both firms’ prices, but also on the previous round’s market demand. In her design subjects (representing firms) played two sequences of 25 rounds. In each sequence firm were matched with different firms (but the firms’ matching were fixed across each sequence of rounds). In every round, each firm made a price decision and then the computer program calculated the sales, profits, and new demand potentials of the two firms. Keser finds that prices
of both low and high cost firms are above the subgame perfect equilibrium prediction (although they are significantly below the myopic monopoly benchmark). This result is especially pronounced in the second sequence of rounds. In a follow-up, Keser (2000) conducted a similar experiment, but with symmetric duopolies (having the same constant marginal cost per unit of production). As in the previous study, she finds that prices are higher than the subgame perfect equilibrium prediction, but they are lower than the myopic monopoly prediction. When she compares these results with the asymmetric case (Keser, 1993), she finds that the degree of cooperation is higher under symmetry. Finally, Bayer and Chan (2007) conducted an additional experiment comparing between a treatment with demand inertia and a treatment without it. In their design, firms played two sequences of 10 rounds, both sequences with the same firm. The authors find that the average prices are lower under demand inertia than in the absence of it. Moreover, except for the last rounds in the second sequence, prices are decreasing over time under demand inertia (also under no inertia) rather than increasing as predicted by the equilibrium.

3.2 Spatial competition experiments

Few experimental studies have tested the spatial competition model à la Hotteling. These studies, with the exception of Camacho-Cuena et al. (2005) and Barreda-Tarrazona et al. (2011), focused on the location decision (imposing best reply price setting strategies). More precisely, Brown-Kruse et al. (1993), and Brown Kruse and Schenk (2000) tested behavior in duopoly markets, while Collins and Sherstyuk (2000) and Huck et al. (2002) tested behavior in triopoly and quadropoly markets, respectively. Brown-Kruse et al. (1993) observe that firms tend to clustered around the center (close to the Nash equilibrium), but when non-binding communication is allowed, firms locate around the
collusive equilibrium.\footnote{It seems that communication was implemented through a chat window (Brown-Kruse et al., 1993, p.146).} In a follow-up, Brown Kruse and Schenk (2000) find that symmetry is a criteria for a focal equilibrium, and that non-binding communication leads to the collusive equilibrium. Collins and Sherstyuk (2000) test a triopoly market. Unlike Brown-Kruse et al. (1993) and Brown Kruse and Schenk (2000) in their design there is no pure-strategy Nash equilibrium. The authors observe location decisions that could be considered in line with the mixed-strategy equilibrium. Finally, Huck et al. (2002) tested a location-setting oligopoly with four firms in a design that includes a pure strategy Nash equilibrium. They observe that behavior is generally inconsistent with equilibrium.

Camacho-Cuena et al. (2005) and Barreda-Tarrazona et al. (2011) conducted experiments in which firms played two stages. In the first stage firms choose locations and in the second stage they decide on the market prices. Camacho-Cuena et al. (2005) find that differentiation between firms is less than predicted by the equilibrium. The study by Barreda-Tarrazona et al. (2011) was particularly designated to test for the two-stage (location and price setting) behavior. In this study the authors observe that the levels of product differentiation are systematically lower than predicted in equilibrium under risk neutrality, but it is compatible under risk aversion. They also find that prices are consistent with collusion attempts. Finally, Orzen and Sefton (2008) investigated price competition in a segmented market. They observe that mixed strategy equilibrium predictions perform better than alternative benchmarks in organizing the data.

4 Proposed experimental design

In the following we portray the design that aims at testing the model by de Almeida Prado (2013). Following Keser (1993, 2000) and Bayer and Chan (2007), each session is consisted of two sequences of rounds (called “runs”), each lasting exactly 20
rounds. Our design aims at testing (a) price competition under demand inertia (where the location decision, “close” or “far”, is determined by the experimenter). (b) the full two-stage model including first a location decision (“close” or “far”) and then a price decision. The parameters chosen for the “close” (firms are relatively close to each other compared to the strength of network effect $J$) and “far” locations are $\delta = 5$, and $\delta = 15$, respectively. Additionally, we set $J = 10$.

Each game (of two participants (“firms”)) starts with $m_0 = 0$, that is, both firms starts with equal market shares. In each period $t$, each player $i$ is asked to set a price $P_t^{(i)}$. The first prices $P_1^{(i)}$ of each pair of firms, $i = 1, 2$, produces the market share difference $m_1$ between player 1 and 2 of period 1. The value of $m_1$ is automatically calculated according to equation (6), where $h_1 = P_1^{(1)} - P_1^{(2)}$:

$$m_1 = \begin{cases} 
-1, & \text{if } m_0 \leq \frac{h_1 - \delta}{J}, \\
\frac{J}{\delta} m_0 - \frac{h_1}{\delta}, & \text{if } \frac{h_1 - \delta}{J} < m_0 < \frac{h_1 + \delta}{J}, \\
1, & \text{if } m_0 \geq \frac{h_1 + \delta}{J},
\end{cases} \quad (15)$$

Based on the value of the market share difference $m_1$, the market shares $|N_1^{(i)}|$ and profits $|N_1^{(i)}| \times P_1^{(i)}$ of players $i = 1, 2$ at period $t = 1$ are calculated, where $|N_1^{(1)}| = (1 + m_1)/2$, $|N_1^{(2)}| = (1 - m_1)/2$. In the next period, each player $i$, of each pair of players, $i = 1, 2$, set a price $P_2^{(i)}$. Since $m_1$ is already available at period 2, $m_2$ is automatically
calculated according to equation (6), where \( h_2 = P_2^{(1)} - P_2^{(2)} \):

\[
m_2 = \begin{cases} 
-1, & \text{if } m_1 \leq \frac{h_2 - \delta}{f}, \\
\frac{J}{\delta} m_1 - \frac{h_2}{\delta}, & \text{if } \frac{h_2 - \delta}{f} < m_0 < \frac{h_2 + \delta}{f}, \\
1, & \text{if } m_1 \geq \frac{h_2 + \delta}{f},
\end{cases}
\]  

(16)

As before, market share and profits of period 2 were calculated: \( |N_2^{(1)}| = (1 + m_2)/2 \), \( |N_2^{(2)}| = (1 - m_2)/2 \) and \( |N_2^{(i)}| \cdot P_2^{(i)}, i = 1, 2 \), and so on.

The game ends when \( t = 20 \). Each player then receives a number of points equal to the sum of the profits in each round: \( \sum_{t=1}^{T} |N_i^{(i)}| \cdot P_i^{(i)} \). This aggregate profit will be exchanged to the relevant currency (e.g., Euro, Brazilian Real) and paid to the firms at the end of the experiment.

We plan to conduct several treatments. We will run treatment where communication between firms is not allowed, and also treatments in which firms are able to engage in non-binding communication before making their location or price decisions. Investigating the effect of non-binding communication in our experiment is especially interesting because although in theory such communication should have no effect on behavior (it is often referred to as “cheap talk”), in practice it has a considerable effect on collusion (e.g., see Fonseca and Normann, 2012; Waichman et al., 2014; Brown-Kruse et al., 1993, and Brown Kruse and Schenk, 2000 in oligopoly experiments à la Bertrand, Cournot, and Hotteling, respectively). Our proposed series of treatments deal with symmetric firms, but we plan to extend the research also to cases where firms are heterogeneous with respect to one or some parameters. The proposed experimental design is portrayed in Table 1.

We designed the treatments in Table 1 in order to answer the following blocks of
Location decision: Exogenous (close) Endogenous (close or far)

| Without network externality and no communication | 1a  | 2a  | 3a  |
| With network externality and no communication  | 1b* | 2b* | 3b  |
| Without network externality and communication  | 1c  | 2c  | 3c  |
| With network externality and communication    | 1d  | 2d  | 3d  |

The values within each cell denotes the treatment name for further reference, whereas * denotes treatments which were already tested and pre-test have been achieved.

Tabela 1: The experimental design

research questions:

RQ1: **What is the effect of network on collusion**

(a) **in a price competition game where products are roughly homogeneous (located close to each other)?** [Comparing treatments 1a-1b]

(b) **in a price competition game where products are roughly heterogeneous (located far to each other)?** [Comparing treatments 2a-2b]

(c) **in a location and price competition game?** [Comparing treatments 3a-3b]

RQ2: **What is the effect of non binding communication on collusion**

(a) **in a price competition game where products are roughly homogeneous (located close to each other)?** [Comparing treatments 1a-1c]

(b) **in a price competition game where products are roughly heterogeneous (located far to each other)?** [Comparing treatments 2a-2c]

(c) **in a location and price competition game?** [Comparing treatments 3a-3c]

RQ3: **What is the effect of non binding communication on collusion under network effects**
(a) in a price competition game where products are roughly homogeneous (located close to each other)? [Comparing treatments 1b-1d]

(b) in a price competition game where products are roughly heterogeneous (located far to each other)? [Comparing treatments 2b-2d]

(c) in a location and price competition game? [Comparing treatments 3b-3d]

RQ4: What is the effect of network when communication is allowed

(a) in a price competition game where products are roughly homogeneous (located close to each other)? [Comparing treatments 1c-1d]

(b) in a price competition game where products are roughly heterogeneous (located far to each other)? [Comparing treatments 2c-2d]

(c) in a location and price competition game? [Comparing treatments 3c-3d]

4.1 Experimental procedure and program

The suggested experiment is computerized, it was programmed using the z-Tree experimental software (Fischbacher, 2007). Subjects (each representing a firm) play two runs (sequences of rounds) where in the first stage of each run (in treatments 3a,b,c,d where it is played) each firm choose either to be located close to or far from their matched firm. During the consequences rounds firms are informed where they are located (in relation to their matched firms).\(^5\) In each of following rounds (a total of 20 rounds) firms make price decisions. After each round, each firms learn about its price, the price of its matched firm,

\(^5\)If both players choose “far” than \(\delta = 15\), otherwise \(\delta = 5\).
its market share, its profit, the profit of its matched firm, and its accumulated profit in the run so far.

Since it is quite complicated to compute the consequences of such a market with network effects we took on the following measures: First, we conduct two runs. The first run, although being paid, is mainly done to allow subjects to learn the dynamics of the game. Second, we use a “dynamic profit calculator” that calculates profit for the future 10 rounds given the current market shares of both firms. In this calculator each subject has to feed (input): his/her price and the price of the other firm. Unlike previous profit calculators (e.g., see Requate and Waichman, 2011) each firm could also feed the number of rounds, \( r \), where these prices hold \( (r \leq 10) \) and to specify a new set of prices for the remaining \( (10-r) \) rounds. Once entering the inputs, the device provides information about the firms’ and their rival firms’ simulated prices, market shares, profits in each of the simulated following 10 rounds, and the accumulated profits in the 10 rounds. Figure 2 shows the input field of the calculator, while Figure 3 presents the full calculator (input and feedback) integrated in the price decision screen. Notably, in the actual game firms can choose every round a different price, while the calculator only allows for one change of prices within 10 rounds. The idea was to provide subjects with a sufficiently simple tool that would help them understand the dynamics of the game. Such a device may be especially useful in experiment where the optimal strategy is to offer low prices in the first rounds in order to dominate the market, and then to increase the price. Third, we will run the experiment in context of “night club” that is more intuitive than under abstract framing. The framing is as follows: “Each subjects represent an owner of a night club. The demand for the night club depends on your current price and on the number of people attended your night club in the previous round. Subjects decide about prices ranging

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6The market share of its matched firm is also provided as the market shares of both firms amounts to 1.

7In contrast to other experiments in economics, oligopoly experiments are usually in context of firms who choose prices or quantities (e.g., Huck, 2004).
The following figures shows the computer screens. Figure 1 present the location decision “close” or “far” for the cases it is endogenously determined by the firms. Figure 2 shows the input field of the profit calculator, while Figure 3 shows the decision screen in a given round.

5 Pre-test results

In September 2013 we conducted some sessions at campus Ribeirão Preto of the University of São Paulo, Brazil. We have conducted two treatments with network externality but when location was either sufficiently close or sufficiently far (these treatments correspond to Treatments 1b and 2b in Table 1). The result we presents in this section are of the second run of each treatment where subjects are assumed to understood the environment and the dynamics of the game.

Our preliminary results seems to be quite in line with theory. In the treatment where firms were located close to each other (e.g. products are roughly homogeneous) the average price is very low (which corresponds to the subgame perfect equilibrium of the game in which the market leader choose a price of 5 and the follower choose a price of 0). The results on average price setting are presented in Figure 4. Moreover, Figure 5 presents the evolution of markets prices and market shares (demand) of two pairs of firms. In this cases one can see that once one firm dominated the market, it chose a price of about 5 ECU, where it still have all the market share (because choosing a too high price in relation with its matched firm may result in loosing market shares). At this point the matched firms chose minimum price but in vain (the gap between prices of the two firms was not large enough to attract consumers).

In the treatments where firms are located far from each other (e.g. products are
roughly heterogeneous) the average price is about 5 ECU (which corresponds to the subgame perfect equilibrium of the game in which both players choose a price of 5). Figure 5 illustrates the evolution of markets prices and market shares (demand) of two pairs of firms. In these cases since products are differentiated, when the differences in prices between the firms are not too large there is hardly gain of market shares.

6 Budget

Referências


Huck, S., Müller, W., and Vriend, N. J. (2002). The east end, the west end, and king’s cross: on clustering in the four-player hotelling game. *Economic Inquiry*, 40:231–240.


The first stage in treatments where it is displayed. Subjects choose whether to be located close to or far from the other firm

Figura 1: The location-decision screen.

In this example a subjects calculates the profits under the following condition in the first 6 rounds his price is 1 the other firm price is 5. The the remaining 4 rounds he increases his price to 10, while the other firm price is 5.

Figura 2: The input of the profit calculator
The profit calculator is located on the left-hand side of the screen. The results of the previous round are shown on the upper right-hand side of the screen, while the price decision is made on the bottom right-hand side. Given the input inserted to the profit calculator (see Figure 2) the calculator indicate that the firm will have the whole market share already in the next second round, which lead to a profit of 45.90 ECU after 10 rounds. The history of actual play indicate that both firms chose a price of 5 in the previous round and share the market equally (each receiving a profit of 2.5 ECU so far).

Figura 3: The price-decision screen (round 2 of 20).
Figura 4: Median prices across different markets in Treatments 1b (above) and 2b (below).
Figura 5: Dynamics of price and market shares (demands) of two pairs of firms located close to each other (Treatment 1b).
Figura 6: Dynamics of price and market shares (demands) of two pairs of firms located far to each other (Treatment 2b)