Controlling Monopoly Power in a Double-Auction Market Experiment*

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Abstract

There is robust evidence in the experimental economics literature showing that monopoly power is affected by trading institutions. In this paper, we study whether trading institutions themselves can shape agents' market behavior through the formation of anchors. We recreate experimentally five different double-auction market structures (perfect competition, perfect competition with quotas, cartel on price, cartel on price with quotas, and monopoly) in a within-subject design, varying the order of markets implementation. We investigate whether monopoly power endures the formation of price anchors emerged in previously-implemented market structures. Results from our classroom experiments suggest that double-auction trading institutions succeed in preventing monopolists from exploiting their market power. Furthermore, the formation of price anchors in previously-implemented markets negatively impacts on monopolists' power in later market structures.

Keywords: Double Auctions; Perfect Competition; Monopoly, Market Imperfection; Spillovers; Anchors; Classroom Experiments.

JEL code: C90, D41, D42, D43, D44

1 Introduction

The quest for controlling market power has paved the way to the modern experimental economics literature. Since the seminal works by Chamberlin [1948] and Smith [1962], scholars have tried to show that the power of agents operating in markets can be sensitive to the trading mechanisms devised. For example, Smith and Williams [1981] conducted a series of laboratory market experiments designed to investigate whether the rules of market trading mechanisms might discipline a monopolist. It turned out that public posting of uniform prices in a Posted Offer Auction eliminates the incentive to offer discounts on marginal units that arises in a Double Auction.

In experimental markets with the same number of buyers and sellers, trading prices and traded quantity quickly converge to the competitive equilibrium price

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and quantity under Double Auction. Furthermore, the efficiency reached by double-auction markets closely approximates that reached at the competitive equilibrium. As shown by Smith [1962] and subsequent experimental research on competitive markets (see, e.g., Friedman and Rust [1993]; Attanasi et al. [2020]), the convergence and efficiency properties of double-auction markets with human traders are robust to modifications of trading periods length. In particular, only few trading periods are needed to get traded quantity and price to converge to the competitive equilibrium levels and the market to reach full efficiency. This empirical result is also confirmed by thorough theoretical analysis (see, e.g., Chatterjee and Samuelson [1983], Wilson [1985], Gresik and Satterthwaite [1989], Satterthwaite and Williams [1989], and Cripps and Swinkels [2006]).

As for monopolistic markets, prices set by monopolists under double-auction trading mechanisms are significantly lower than those the theory predicts, converging towards perfect-competition levels (see Holt et al. [1986], Smith and Williams [1989], and Davis and Williams [1991]). On the other hand, experimental work has also provided conflicting evidence. In search for evidence proving that double-auction markets are able to control over monopoly and monopsony power, Muller et al. [2002] find that double-auction trading mechanisms provide an ineffective constraint to market power and do not succeed in preventing agents with market power from exploiting their advantage. Similar results are reported in Ledyard and Szakaly-Moore [1994], Brown-Kruse et al. [1995], and Godby [2000, 2002].

While the choice of the trading mechanisms has a significant impact on monopolistic market equilibrium, it is not clear how the presence of behavioral tendencies, combined with that of particular trading mechanisms may affect monopoly power. It is common wisdom in the experimental literature that subjects use formerly traded prices as *anchors*, namely, the regular price that they expect to pay for a given good (Thaler [1985], Isoni et al. [2011], Bordalo et al. [2012], Putler [1992]).[1] Seminal works in the experimental economics literature have proven the ubiquitous presence of such anomalies in subjects' behavior, even in repeated trading interactions. Kristensen and Gärling [2000] suggest that offers and counteroffers in trades are generated through an anchoring-and-adjustment process. The *shaping hypothesis* proposed by Loomes et al. [2003], states that in repeated auctions in which prices have no information content, there is a tendency for agents to adjust their bids towards the price observed in the previous market period. Tufano [2010] shows that market behavior is not anomaly-free, strengthening Loomes and coauthors' results. Also out-of-the-lab studies of auctions have shown that game history and subjects' experience do matter in the analysis of price convergence, bids and sold quantity. Pownall and Wolk [2013] show that experience significantly lowers the level of bids suggesting that bidders change their bidding behavior throughout time, eventually eliminating previous overbidding. These studies confirm that market behavior is not the product of the true underlying preferences but rather of context-dependent

[1]It is worth noting that anchors should be distinguished from *reference points* [Kahneman, 1992] in that an anchor affects the estimates of an outcome, while reference points concern the neutral point (or *status-quo*) that defines gains and losses according to an individual's preferences. In the case of trades, reservation prices define one's reference point, while initial offers represent price anchors. The offer-and-counteroffer process causes the adjustment and shifts of initial anchors (Kahneman [1992], Kristensen and Gärling [2000]). Our work relates to anchors rather than to reference points.

preferences.

Drawing from this experimental evidence, we design a double-auction classroom experiment with undergraduate students in Economics to understand whether the implementation of double-auction trading institutions creates a constraint over monopoly power and whether such effect is modulated by the formation of anchors created in previous markets. In particular, we hold double-auction trading under different market structures – perfect competition with and without quotas, cartel with and without quotas, monopoly – and vary, across treatments, their implementation order. With this, we aim at investigating whether monopoly power depends on subjects' experienced prices under previously-implemented market structures.

We derive our experimental hypotheses by informing a standard equilibrium model with behavioral insights from the experimental literature on anchoring effects (Kahneman et al. [1982], Tversky and Kahneman [1992], and Kristensen and Gärling [1997]). First, we study sellers' behavior in each of the five market structures separately. Then, we model the evolution of trading prices according to the order of implementation of the five market structures. In our theoretical framework, we assume that sellers are heterogeneous in their bargaining toughness when negotiating with buyers (see, e.g., Attanasi et al. [2013]) and that, by moral balancing theory (Nisan and Horenczyk [1990]), they keep account of their self-image of tough bargainers as market structures unfold.

In line with the predictions of our behavioral model, our results provide indications that, under double-auction trading, prices prevailing in monopolistic markets are far lower than those predicted by the theory. On average, prices in monopoly start out relatively low since the first period, to then decrease as the experiment unravels. Moreover, if the monopoly comes after other market structures, the formation of price anchors in prior market structures weakens the monopolist's market power. In particular, when subjects in the experiment first trade under perfect competition, prices are lowest than when either cartel or no market precedes the monopoly.

Our work and results are relevant in the light of recent economic directions pointing towards the erosion of competition in markets and a steady rise of monopoly power (Eggertsson et al. [2018]). Recent work in economics has focused on future trends of monopolistic power, firm concentration and profit increase. For example, the share of total U.S. stock market value reflecting monopoly power rose from negligible levels in 1985 to around 80% in 2015 and it seems to grow steadily (Kurz [2017]). Other authors have reported evidence of increasing firms' market power and concentration along with rising pure profits (Dorn et al. [2017], Grullon et al. [2019]). In such circumstances, policymakers are often called to intervene and regulate markets by either favoring competition or granting monopoly power to privates. The reasons why policymakers may prefer granting a monopoly are several. Economies of scale are one among others, with utility companies representing a relevant example in this regard.[2]

The government may also grant sole ownership of inventions through patent laws to help eliminate the market failure that is likely to occur in the markets

[2]For theoretical studies showing that monopolistic price discrimination and reduced competitive pressure are able to solve market inefficiencies in specific environments, see, respectively, Flanders et al. [2020] and Zimper and Molefinyane [2020].

for those goods. In evaluating policies in favour of coercive monopoly, regulators should account for the role of trading institutions as well as for behavioral fallacies typical of agents operating in markets. Such factors together inevitably affect market outcomes. In this effort, our work contributes to the growing body of experimental and theoretical literature complementing standard economic models with bounded rationality and psychological biases to better evaluate the impact of public policies (see, e.g., Gabaix et al. [2016], Gabaix [2020]).

The remainder of the paper is as follows: Section 2 discusses the experimental design; in Section 3 we present our model and theory-driven hypotheses; Section 4 reports the experimental results. Lastly, Section 5 concludes.

2 Experimental design

2.1 Market structures

Following Smith [1962] and subsequent standard practices in market classroom experiments (see, e.g., Holt [1996], Cason and Friedman [2008]; Attanasi et al. [2016]), we recreate an experimental, computerized double-auction laboratory market.

Table 1 describes the main features of each market structure of our design (see Appendix C for the experimental instructions). We implement overall a total of five market structures in a within-subject design.

Table 1: Market structures

Market	**No. Buyers**	**No. Sellers**	**No. Markets**	**Q per Seller**
Monopoly	6	1	4	6
Perf. Comp.	24	4	1	24
Perf. Comp. - quotas	24	4	1	6
Cartel	24	4	1	24
Cartel - quotas	24	4	1	6

In each experimental session, $n = 28$ subjects are randomly assigned to the role of seller or buyer: 4 of them are sellers and the remaining 24 are buyers. Subjects keep the same role for the whole experiment. They play the five market structures in Table 1. Every market structure is played for 3 periods and a single trading period lasts 120 seconds.[3] At the beginning of the experiment, subjects only know that the experiment consists of five phases (market structures), with instructions of each new phase distributed only prior to that phase.

In each trading period, sellers' costs and buyers' valuations of a homogeneous good are exogenously given: each buyer is endowed with a valuation v_i, which varies

[3]Note that, although there is not a per period time constraint in the pioneering study of Smith [1962], a per period time limit has later become a quite standard feature of market classroom experiments, especially in computerized ones: see Wells [1991] for double-auction mechanisms and Holt [1996] and Ruffle [2003] for other trading mechanisms. This is a necessary feature in order to experimentally allow intramarginal inefficiency, which has been shown to be a relevant source of inefficiency in electronic markets (see, e.g., Cason and Friedman [1996]). Intramarginal inefficiency is also a reliable measure of subjects' learning across trading periods, as we show in the data analysis of Section 4.

across buyers, while the four sellers face the same production cost c. Therefore, each buyer only knows his own valuation and the fact that all sellers face the same production cost; each seller knows the cost of all sellers and the fact that buyers' valuations are heterogeneous. Valuations are described by the step function with values $v_i \in \{20, 18, 16, 14, 12, 10\}$ (see Figures A.1-A.3 in Appendix A). More precisely, in each trading period there are 4 buyers with the same v_i (i.e., 4 buyers with $v_1 = 20$, 4 buyers with $v_2 = 18$, ..., and 4 buyers with $v_6 = 10$). The cost c is set at 12 for every seller. Valuations are re-shuffled and randomly re-assigned to buyers at each trading period.

For each seller-buyer transaction, the profit of seller S_j ($j = 1, 2, 3, 4$) is given by the difference between the trading price and his production cost, formally $\Pi_{S_j} = p - c$; the profit of buyer B_k ($k = 1, 2, ..., 24$) is given by the difference between the assigned valuation and the trading price, formally $\Pi_{B_k} = v_{ik} - p$. Negative profits are not allowed. In particular, sellers (resp., buyers) are allowed to trade at their cost (resp., valuation), hence, they could get null profits in a given trading period. Yet, we exhort them to earn a positive profit for each traded unit.[4] Transferring profits from one trading period to another is not allowed (every time a new period starts, subjects' profits are reset to zero).

Due to the short duration of trading periods, sellers' asks and buyers' bids are constrained to be integer numbers between 0 and 30 experimental points, i.e., the minimum positive profit is equal to 1 point. In each trading period, each buyer can buy at maximum one unit of the good; in line with our research objective, sellers are allowed to sell more than one unit of the good.

Trading is done through a double-auction mechanism. During the trading period, subjects are always shown the current lowest ask and highest bid. Every subject can improve on the existing situation (*improvement rule*): a seller can submit an ask only if lower than the current lowest ask (descending auction), and a buyer can submit a bid only if higher than the current highest bid (ascending auction). When a seller and a buyer reach an agreement, the buyer exits the market, the standing asks and bids are removed, and new asks and bids can be submitted without considering the previous trading price (*market clearing rule*). The trading prices are disclosed on the screens of all subjects in chronological order together with the IDs of the seller and buyer reaching that agreement. An example of the computer screen of sellers and buyers during a trading period is reported in Appendix A.[5]

All of the above is independent of the market structure. Let us now discuss in detail each of the five **market structures** presented in Table 1.

Monopoly. The 28 subjects in the experimental session are randomly allocated to 4 markets, with 1 seller and 6 buyers per market. Each market is characterized by

[4]Notice that this was not an obligation but a suggestion made to participants. This means that our subjects were encouraged to earn positive profits. Such an experimental recommendation is important for direct comparison of our classroom experiment with incentive compatible experimental studies.

[5]Figure A.4 refers to the screen of seller S_1 and Figure A.5 refers to the screen of buyer B_6, in the first trading period of a market under Perfect Competition. They show a moment of the trading period where 5 units are already traded (thus, $24 - 5 = 19$ units are still available for purchase and $96 - 5 = 91$ are still available for sale), seller S_1 has sold 2 of these units, buyer B_6 has not bought yet, the current highest bid is 15 (made by buyer B_{10}), and the current lowest ask is 16 (made by seller S_4).

the same supply function – the seller owning 6 units of the good at a cost of $c = 12$ each –, and the same demand function – with each of the six buyers being assigned one of the six possible valuations $v_i \in \{20, 18, 16, 14, 12, 10\}$. Each subject remains in the same market for the 3 trading periods. The trading mechanism being double auction, price discrimination is allowed for each of the units traded within a period (see Figure A.1).

Perfect Competition. In each of the 3 trading periods, there are 4 sellers with $c = 12$, and 24 buyers with each buyer being randomly assigned one of the six v_i: 4 buyers have $v_1 = 20$, 4 have $v_2 = 18$, 4 have $v_3 = 16$, 4 have $v_4 = 14$, 4 have $v_5 = 12$, and 4 have $v_6 = 10$. Each seller owns 24 units of the homogeneous good, with which he can face alone all the buyers' demand. With this, the competitive market is characterized by 96 available units of the homogeneous good, with at most 24 of them being tradable (see Figure A.2).

Cartel. It is similar to Perfect Competition apart from the four sellers going through a pre-trading stage called "communication stage" in which each of them is asked to privately report his target trading price within $\{0, 1, ..., 30\}$ points, as the price he would like to apply to all his units in the following three trading periods. The experimenter collects the price proposal of each seller, computes the average of the four prices, and disclose it to the four sellers, suggesting that such average price is the only one that they should offer in each trading period.[6] Buyers are informed about the rules of the communication stage, but not about the outcome. The communication stage is intended to allow sellers to form a price cartel. However, sellers are told that they are not committed to offer in the following double-auction trading periods either their own or the average proposed price in the communication stage. Therefore, no additional constraint on trading is imposed with respect to Perfect Competition (see Figure A.3).

Perfect Competition with quotas and **Cartel with quotas**. Under both Perfect Competition and the Cartel structures, we distinguish between a "regular" market and one in which restrictions on the quantity endowed to sellers, called "quotas," are applied. In particular, in the latter each seller is only endowed with 6 units of the homogeneous good, with which he can face alone 1/4 of the buyers' demand. With 4 sellers in the market, the total supply of 24 units is equal to the maximum quantity buyers can buy. This leads to other two market structures, with quotas: one under Perfect Competition (Figure A.2 with $\bar{Q} = 24$) and another under the Cartel structure (Figure A.3 with $\bar{Q} = 24$).

2.2 Experimental Procedures and Treatments

Experimental sessions were run in the Laboratory of Experimental Economics of Strasbourg (LEES) by two of the authors. The experiment was computerized using the online platform www.econplay.fr. Individual cubicles ensured subjects' anonymity and the absence of communication during the experiment.

In total 1008 students participated in the experiment (336 per year), in 36 different sessions (12 sessions per year) with 28 students in each session. Each session

[6] Note that, to preserve sellers' anonymity by avoiding noisy communication among them, sellers cannot chat or send proposals among them.

was followed by a tutorial in Microeconomics, where the teacher (same as the experimenter) introduced the (standard) theoretical predictions of Section 3.1 to students, and then analyzed and discussed the experimental data in the light of these predictions. The sessions took place throughout three consecutive academic years (November–December, 2014–2016). Subjects were equally balanced in gender (45% female) and homogeneous in other features: age (almost all students were 18-20 years old), nationality (90% French) and field of study (Economics and Management). As it is common in classroom experiments, we did not use monetary rewards to incentivize subjects. Previous studies have shown that classroom experiments, especially with undergraduate students in Economics, are good at replicating textbook and theoretical predictions (see, e.g., Holt [1996, 1999], Finley et al. [2019]).

The experiment was implemented according to 12 treatments, with 3 sessions (Microeconomic classes) for each treatment, the latter being shown in Table 2. The 3 sessions of the same treatment were implemented in 3 non-consecutive classes. As Table 2 reports, in each of the 12 treatments students were presented, at a within-subject level, the five market structures described in Section 2.1: Perfect Competition (Comp), Perfect Competition with quotas (Comp-q), Cartel (Cartel), Cartel with quotas (Cartel-q), and Monopoly. The treatments differed at a between-subject level according to the order of presentation of the five market structures.

Table 2: Order of presentation of the five market structures

Treatments	Timeline				
	1	**2**	**3**	**4**	**5**
(1) CoCaMo	Comp	Comp-q	Cartel	Cartel-q	Monopoly
(2) CoMoCa	Comp	Comp-q	Monopoly	Cartel	Cartel-q
(3) CaCoMo	Cartel	Cartel-q	Comp	Comp-q	Monopoly
(4) CaMoCo	Cartel	Cartel-q	Monopoly	Comp	Comp-q
(5) MoCoCa	Monopoly	Comp	Comp-q	Cartel	Cartel-q
(6) MoCaCo	Monopoly	Cartel	Cartel-q	Comp	Comp-q
(7) CoCaMo-q	Comp-q	Comp	Cartel-q	Cartel	Monopoly
(8) CoMoCa-q	Comp-q	Comp	Monopoly	Cartel-q	Cartel
(9) CaCoMo-q	Cartel-q	Cartel	Comp-q	Comp	Monopoly
(10) CaMoCo-q	Cartel-q	Cartel	Monopoly	Comp-q	Comp
(11) MoCoCa-q	Monopoly	Comp-q	Comp	Cartel-q	Cartel
(12) MoCaCo-q	Monopoly	Cartel-q	Cartel	Comp-q	Comp

Note: 3 sessions per treatment. ‘Co’, ‘Ca’, and ‘Mo’ stand for Perfect Competition, Cartel and Monopoly, respectively. The ‘q’ symbol following the name of a market structure indicates implementation of quotas within that market.

Given that each market structure was proposed for 3 consecutive trading periods, each treatment was characterized by 15 trading periods, with instructions of each new market structure being shown on the computer screen only at the end of the previous 3 trading periods. Each trading period lasting 120 seconds, the session average duration was about 40 minutes, including the reading of instructions.

Referring to Table 2, we report the main features of our order manipulation at a between-subject level:

- The first group of six treatments of Table 2 (first six rows of the table) share the common feature of implementing structures without quotas first, followed by those with quotas, while in the second group (last six rows of the table) the order without-with quotas is switched.

- Treatment 1 and treatment 7 (first row of each group of six treatments) indicates an order of markets presentation with decreasing structural level of competition (respectively, CoCaMo and CoCaMo-q).

- Treatment 6 and treatment 12 (last row of each group of six treatments) indicates an order of markets presentation with increasing structural level of competition (respectively, MoCaCo and MoCaCo-q).

- The remaining four rows of each group of six indicate treatments with an order of markets presentation leading to non-monotonic structural levels of competition.

- Row-to-row pairwise comparison between treatments in the first and the second group of six allows us to test for the effect of quotas introduced vs. removed within the same market.

3 Experimental Hypotheses

The design of Table 2 is meant to test five theory-driven experimental hypotheses. The theory on which they rely is presented below in two separate subsections.

In Section 3.1, we study sellers' behavior in each of the five market structures separately. In that section, we elaborate predictions on the three periods of each market structure played as first in the treatment sequences of Table 2. The main aim here is to show how a standard equilibrium model predicts different behavior in monopolistic vs. non-monopolistic markets absent previous market history.

In Section 3.2, we enrich our standard equilibrium model introduced in Section 3.1 with behavioral insights from the experimental literature on anchoring effects. By including anchoring effects, we model the evolution of market outcomes according to the order of implementation of the five market structures in the treatment sequences of Table 2. The main aim of this enriched model is to explain different behavior in monopolies played as first market vs. monopolies played after non-monopolistic markets in the treatment sequences of Table 2.

3.1 A model of sellers' competition

We assume that traders have standard preferences within each trading period: each trader aims at maximizing his per-period expected profit. We also assume that traders' preferences are common knowledge, so that, within each trading period, all traders anticipate that the other traders will maximize their per-period expected profits, and so on.

Our theoretical analysis focuses on sellers' market-dependent behavior. We assume buyers' market-independent behavior because of two motivations. First, extensive experimental evidence shows no impact of buyers' behavior on market indexes in double-auction markets like ours, where buyers can only buy one good unit with exogenously assigned valuation for that unit (see, e.g., Holt [1999] and follow-up experimental works).[7] Second, competition among sellers is boosted by design in our experiment. In fact, traders are told by the experimenter that buyers' valuations are heterogeneous, while sellers' cost is homogeneous and hence known among sellers. Therefore, two sellers trading at the same price know they made the same profit, and a buyer making the same bid to two different sellers knows that both have the same leeway to accept that bid.

With this, we put forward a model of sellers' competition in non-monopolistic markets which relies on a feature of market equilibrium. Recall that there are always 4 sellers in each experimental session, operating under the same experimental conditions in 4 distinct markets under Monopoly, and in the same market in the remaining market structures. We will show below that the variance across the 4 sellers' equilibrium traded quantities within a period increases according to the level of competitiveness induced by the market structure. Such a variance is null by construction in equilibrium under Monopoly.

Finally, recall that each market structure is played repeatedly for three trading periods, under the same experimental conditions. In line with the theory of learning in games – which formalizes the idea that equilibrium arises as a result of players' learning from experience due to multiple rounds of play (see, e.g., Fudenberg and Levine [1998, 2009]) – we assume that equilibrium emerges as the third-period outcome of a dynamic process of learning in the first two periods. This is also in line with previous experimental evidence on competitive and non-competitive markets recreated in the laboratory (see Georgantzís and Attanasi [2016] for a survey).

We begin by providing a theoretical analysis of the 4 monopolistic markets.

Monopoly. The experimental implementation of the 4 monopolistic markets allows price discrimination by the monopolist: each monopolist can extract the maximum surplus from the four buyers with $v_i > c$. Given unit cost $c = 12$, valuations $v_i \in \{10, 12, 14, 16, 18, 20\}$, the discrete set of possible prices $\{0, 1, ...30\}$, and the experimental recommendation for both sellers and buyers to make at least 1 point of profit, the vector of equilibrium prices in each of the four monopolistic markets will be $(19, 17, 15, 13)$, with equilibrium traded quantity $q^*_{Mo} = 4$ (with $66\% = 4/6$ buyers trading) and the monopolist's surplus equal to 16, i.e., 4 points per traded unit, as reported in Figure A.1. In fact, given the timing of price discrimination within a trading period, the monopolist first trades with $v_1 = 20$, the buyer with highest v_i, and makes the last trade with $v_4 = 14$, the buyer with lowest $v_i > c$. Therefore, the average price applied by the monopolist is decreasing in the traded quantity in a period: it is equal to 19 for $q_{Mo} = 1$, 18 for $q_{Mo} = 2$, 17 for $q_{Mo} = 3$, and 16 for $q_{Mo} = 4$. We define $p^*_{Mo} = 16 = (19+17+15+13)/4$ as the average equilibrium price in each of the four monopolistic markets. Considering the four markets together, the equilibrium quantity is $Q^*_{Mo} = 4 \cdot q^*_{Mo} = 16$. Note that, to avoid loss of reputation in terms of bargaining power from the first to the third trading period, the monopolist

[7] In particular, Attanasi et al. [2020] show that increasing the market size by four times (from 10 to 40 or from 20 to 80 traders) does not affect buyers' behavior under double auction. This especially applies to our market structures since, when moving from Monopoly to any of the other four market structures, the number of buyers (and sellers) increases by four times.

will never trade with a buyer at a price $p_{Mo} = c = 12$. This would increase the per period traded quantity by allowing also $v_5 = 12$ to trade, although leaving the monopolist's surplus unaffected and decreasing the buyers' expected trading price in the next period. Finally, due to the monopolist's learning of the maximum surplus he can extract from each buyer in his market, behavior will converge to (Q^*_{Mo}, p^*_{Mo}) as trading periods unfold.

We now study the four non-monopolistic market structures, starting from the one with the most competitive market rules.

Perfect Competition. The demand and supply functions in Figure A.2, together with the discrete set of possible prices $\{0, 1, ...30\}$, and the experimental recommendation for both sellers and buyers to make at least 1 point of profit, lead to an equilibrium quantity and price under Perfect Competition of $(Q^*_{Co}, p^*_{Co}) = (16, 13)$,[8] i.e., 66% of buyers (16/24) trade in equilibrium, which is the same equilibrium quantity of the four monopolistic markets considered together, i.e., $Q^*_{Co} = Q^*_{Mo}$. Figure A.2 also represents the sellers' total surplus, equal to 16, i.e., 1 point per traded unit. The seller's per-unit surplus is 3 points lower than under Monopoly, because of the average mark-up: $p^*_{Mo} = p^*_{Co} + 3$. The four sellers considered together under Perfect Competition would obtain the same surplus as the unique seller would get in each of the four monopolistic markets. As for individual behavior, each seller sells on average 4 of his 24 units, although any supply vector $(q^*_j)^4_{j=1}$ with $q^*_j \in \{0, 1, ..., 16\}$ and $\sum_{j=1}^4 q^*_j = 16$ is an equilibrium. Therefore, it is possible that all $Q^*_{Co} = 16$ is traded in equilibrium by only one, only two or only three of the four sellers. More precisely, across the 969 possible equilibrium vectors of sellers' traded quantities $(q^*_1, q^*_2, q^*_3, q^*_4)$ there is only one equalizing the four quantities. This leads to substantial sellers' competition in traded quantities within a period, along with the law of demand, i.e., with sellers trading more quantities who will do it at a lower average price. In particular, to increase his market share, a seller could also trade at price $p_{Co} = c = 12$, thereby allowing also $v_5 = 12$ to trade. Trading at no-profit leaves the seller's individual surplus unaffected but decreases the buyers' and the other three sellers' expected trading price in the next period. This in turn accommodates convergence of the trading price toward $p^*_{Co} = 13$ in the third period, since no-profit trades at $c = 12$ increase competitive pressure on sellers, who will make their best to make 1 point of profit for each traded unit in the last period.

Cartel. The equilibrium quantity and price depend on whether sellers reach a mutual agreement on a unique price to maximize the sellers' total surplus and share it equally. Recall that the mutual agreement in the experiment is made available to the four sellers as the (unique) average of the four trading prices privately reported in the (pre-trade) communication stage.[9] Thus, collusive strategies among the four sellers should lead them to privately report (and coordinate on) the price they would impose

[8] Indeed, p^*_{Co} lies in the interval $[12, 14]$. Asks and bids being constrained to integer numbers, this interval shrinks to $\{12, 13, 14\}$. Given $c = 12$ for each seller and buyers' valuations in $\{10, 12, 14, 16, 18, 20\}$, $p^*_{Co} = 13$ is the only price where each traded unit makes a positive profit for both the sellers and the four intramarginal buyers with $v_4 = 14$. With this, the four buyers with $v_5 = 12$ become extramarginal.

[9] Note that, differently from Monopoly, sellers are not given the possibility to coordinate on price discrimination strategies, since this collusion device would be hard to implement in the experiment and for sellers to maintain.

under a monopoly with unique price. The quantity-price combination maximizing the monopolist's total surplus under a unique price is $(Q^*_{Ca}, p^*_{Ca}) = (8, 17)$, i.e., only 33% of buyers (8/24) trade in equilibrium, with each seller only selling on average 2 of his 24 units (equilibrium supply vector $(q^*_j)^4_{j=1}$ with $q^*_j \in \{0, 1, ..., 8\}$ and $\sum^4_{j=1} q^*_j = 8$). Figure A.3 shows that in this case the sellers' total surplus equals to 40 overall (5 points per traded unit on average), although this is lower than under monopoly with price discrimination due to lower equilibrium quantity. However, in our setting agreements are not binding and so undercutting cannot be prevented, since sellers are free to set any price they want to. Thus, there is an individual incentive to deviate from the collusive outcome to increase the seller's traded quantity and individual surplus. Therefore, sellers should not be able to maintain the cartel agreement mentioned above, with the uniperiodal quantity-price combination converging to the one of Perfect Competition, i.e., $(Q^*_{Co}, p^*_{Co}) = (16, 13)$ as trading periods unfold. Within this process, sellers trading more quantities will do it at a lower average price, since tit-for-tat behavior after betrayal of the cartel agreement will lead a seller to decrease his ask in order to attract further buyers to sell more. Thus, as under Perfect Competition, to increase his market share and/or to retaliate against other sellers after cartel betrayal, a seller will also trade at price $p_{Co} = c = 12$. This in turn accommodates price cartel betrayal through price undercutting as trading unfolds, with trading price converging from the cartel price $p^*_{Ca} = 17$ in the first trades of period 1 to the competitive price $p^*_{Co} = 13$ in the last trades of period 3. Hence, convergence to the equilibrium price is from above.

Perfect Competition with quotas and **Cartel with quotas**. The introduction of quotas does not affect the market equilibrium outcomes in either Perfect Competition or Cartel. In fact, given a quota of 6 units per seller, the total supply of 24 units is sufficient to guarantee $Q^*_{Co} = 16$ and $Q^*_{Ca} = 8$, respectively. However, the equilibrium supply vector $(q^*_j)^4_{j=1}$ is constrained to $q^*_j \in \{0, 1, ..., 6\}$, with $\sum^4_{j=1} q^*_j = 16$ under Perfect Competition (Figure A.2) and $\sum^4_{j=1} q^*_j = 8$ under the Cartel (Figure A.3). Therefore, given that none of the four sellers is able to satisfy alone all the equilibrium market demand in any of the two market configurations, the lower pressure on the supply side may lead to a decrease in the traded quantity and an increase in the trading price, with average $p_{Co-q} > p_{Co}$ under Perfect Competition with quotas and average $p_{Ca-q} > p_{Ca}$ under Cartel with quotas. This effect should be greater in the Cartel with quotas ($p_{Ca-q} > p_{Co-q}$), since sellers can account for the individual rationing when reporting their (higher) target trading price in the (pre-trade) communication stage and when trying to maintain it through the three trading periods. However, due to non-binding cartel agreement, also in this case the seller's average trading price should converge to p_{Co-q} as trading periods unfold. Finally, the introduction of quotas leads to a significantly lower number (i.e., 149) of possible equilibrium vectors of sellers' traded quantities $(q^*_1, q^*_2, q^*_3, q^*_4)$ and the need of at least three out of the four sellers to trade in order to provide the competitive market equilibrium quantity $Q^*_{Co} = 16$. Therefore, despite not changing the market equilibrium quantity, quotas reduce competitive pressure among sellers, thereby leading to convergence to p^*_{Co} from above. This in turn reduces both the negative correlation between sold quantity and average trading price at seller individual level and the fraction of sellers trading at zero profit with the aim of increasing their market share. The latter is prevented by individual rationing, which incentivizes each seller to try to obtain a positive profit on each of the 6 allowed traded units.

Table 3 summarizes our predictions as for the average trading price, its correlation with the traded quantity, and the number of zero-profit trades in each of the five market structures. As for the average trading price, we introduce two parameters $\eta, \nu > 0$ with $\eta + \nu < 3$. Parameter η accounts for the positive differences $(p^*_{Co-q} - p^*_{Co})$ and $(p^*_{Ca-q} - p^*_{Ca})$ due to the effect of quotas. Parameter ν accounts for the positive differences $(p^*_{Ca} - p^*_{Co})$ and $(p^*_{Ca-q} - p^*_{Co-q})$ due to the (non-binding) cartel agreement during the pre-trade communication stage. The constraint $\eta + \nu < 3$ highlights that the two effects considered together are not enough to lead to a monopolistic configuration. Note that, because of our learning hypothesis, the predictions shown in Table 3 should especially hold in the third period of each market structure. In fact, the implementation of three trading periods for each market structure in our design is meant to allow subjects to learn across periods.

Table 3: Predictions on market structures comparison ($\eta, \nu > 0$ with $\eta + \nu < 3$)

Market Structures	Average p	Correlation with Q	Trades at $p = 12$
Monopoly	16	High	None
Comp	13	High	Many
Comp-q	$13 + \eta$	Low	Few
Cartel	$13 + \nu$	High	Many
Cartel-q	$13 + \eta + \nu$	Low	Few

All of the above leads to our first three theory-driven experimental hypotheses, which concern sellers' behavior in market structures regardless of the order of presentation in the twelve treatments of Table 2.

The first experimental hypothesis concerns the negative relationship between a seller's traded quantity and average trading price in the five market structures of our experiment (second column of Table 3). This negative relationship is the main theoretical feature of optimal monopolistic behavior.

Hypothesis 1. Average trading price in a monopolistic market decreases with the monopolist's traded quantity. The same holds for each seller under both Perfect Competition and Cartel. The introduction of quotas mitigates this negative relationship.

The second experimental hypothesis (last column of Table 3) concerns trading with zero profit as a seller's strategy to increase his market share under Perfect Competition and as a punishment of co-players' deception of the Cartel agreement. Conversely, we have shown that monopolists have no incentive to trade at their unit cost, and that in non-monopolistic markets the introduction of quotas mitigates such incentive.

Hypothesis 2. The fraction of zero-profit trades is higher for sellers under both Perfect Competition and Cartel than under Monopoly. The introduction of quotas mitigates these two positive differences.

Third, we want to check that equilibrium prices under each market are in line with our predictions, summarized in the second column of Table 3. If so, we ought to observe *weak monotonicity* of average trading prices moving from Perfect Competition to Cartel and from Cartel to Monopoly, with the introduction of quotas smoothing these two increases.

Hypothesis 3. Average trading prices increase or do not decrease by going from Perfect Competition to Monopoly, formally:

$$p_{Co} \leq p_{Co-q} \leq p_{Ca} \leq p_{Ca-q} \leq p_{Mo}, \tag{1}$$

with the last (resp., the first three) inequalities of Eq. (1) being more likely (resp., are less likely) to be met in the third trading period than in the first two.

In the next section, we focus on the effects of the order of presentation of the five market structures on monopolists' power in the within-subject design of Table 2.

3.2 The effect of price anchoring on monopolists' power

We now build on the within-market equilibrium analysis of Section 3.1 to discuss how outcomes in later-implemented markets are affected by outcomes arising in previous market structures via behavioral components. In particular, we describe how behavioral components – due to previous non-monopolistic behavior – moderate monopolistic power in terms of the sign of the treatment effect. More precisely, we introduce a model that links prices emerged in non-monopolistic market structures with prices emerging in later implemented monopolistic markets. In fact, as reported in Table 2, Monopoly has been implemented in 4 treatments as first market, in other 4 treatments as third market, and in the remaining 4 treatments as fifth market. In the latter two groups of treatments, sellers' behavior in their own monopolistic market may be influenced by inter-seller competition in previously-implemented non-monopolistic markets.[10]

To model this impact, we rely on the psychological literature of cognitive biases (see Kahneman et al. [1982] and follow-up studies) and, in particular, on the role of anchors in negotiations. Tversky and Kahneman [1992] have shown that when negotiating about an object, a deliberate initial price can strongly affect the range of possible offers and counteroffers. Indeed, in the negotiation process, anchoring serves to determine a commonly accepted starting point for the subsequent negotiations. As soon as one side of negotiators states their first price offer, the (subjective) anchor is set. In this regard, several experimental studies have proved that traders' initial offers have a stronger influence on the outcome of negotiations than subsequent counteroffers (see, e.g., Kristensen and Gärling [1997], Kristensen and Gärling [2000]). This way, the process of offer and counteroffer leads to mutually beneficial

[10] Note that subjects were told from the very beginning of the experiment that they were going to play a sequence of five different market structures (see the experimental instructions in Appendix C). With a finite horizon of five market structures (i.e., no uncertainty about the number of repetitions) and a different market structure (i.e., a different repeated game) in each repetition, the Folk theorem for infinitely repeated games does not apply.

agreements distorted toward the first anchor. Attanasi et al. [2016, 2020] show that this anchoring effect especially holds under double-auction mechanisms within the same market structure – perfect competition – repeatedly played for at least three periods.

Building on this literature, we propose a model of price anchoring in which prices prevailing in previously-implemented non-monopolistic markets influence sellers' perceived power – and thus how much tough they can act toward buyers – in later implemented monopolies. This model is based on three assumptions.

First of all, the theoretical analysis of Section 3.1 has shown that the equilibrium price in each of the four non-monopolistic market structures is lower than the average equilibrium price in monopoly with price discrimination. Therefore, rewriting Eq. (1), we assume that, if any, the effect of price anchoring on prices emerging in later implemented monopolistic markets is negative, i.e., it ultimately decreases the average price under Monopoly:

$$p_{Mo} > \max\{p_{Co}, p_{Co-q}, p_{Ca}, p_{Ca-q}\} \tag{2}$$

Second, in line with Attanasi et al. [2013], we assume that agents are heterogeneous in their bargaining toughness in negotiations. By moral balancing theory (Nisan and Horenczyk [1990]), individuals keep account of their self-image over time. Therefore, a seller asking for higher trading prices when acting as a monopolist should also display a similar bargaining toughness when competing with other sellers in non-monopolistic markets. With this, we expect that the average trading price a seller is able to rip under monopoly correlates with the one he is able to rip in each of the four non-monopolistic market structures. Eq. (3) models this correlation. We denote with p_{Mo} the trading price under Monopoly. With $p_{No\text{-}Mo}$ we indicate the trading price in the four *No*n-*Mo*nopolistic markets, with $No\text{-}Mo \in \{Co, Ca, Co\text{-}q, Ca\text{-}q\}$. p_{max} represents the highest trading price a seller is able to rip which is equal to the highest buyer's valuation $v_5 = 20$ regardless of the market structure.[11] Eq. (3) represents the average trading price a seller is able to rip under Monopoly as a convex linear combination between the average trading price he is able to rip in any of the four non-monopolistic markets and the highest possible trading price. The weight $\sigma \in [0, 1]$ affects monopolist's concern for maintaining a tough reputation. A highly-concerned monopolist displays a lower level of σ (hence, a higher level of its complement, $1 - \sigma$).[12]

Such a parameter also represents the correlation between p_{Mo} and $p_{No\text{-}Mo}$, i.e., the seller's keeping of his self-image of bargaining toughness across market structures.

[11] The choice of setting $p_{max} = 20$ in Eq. (3) is meant to represent the monopolist's desire to gain the highest reputational toughness by setting prices to the highest feasible buyer's valuation, i.e., $v_5 = 20$. However, although it is likely that in our experiment trading prices fall below such an upper threshold, setting $p_{max} = 20$ prevents any inconsistency in data interpretation, thereby assuring the portability of our model. In fact, setting $p_{max} < 20$ would change the interpretation of σ for trades with $p_{No-Mo} > p_{max}$ since, for these trades, a higher σ in Eq. (3) would indicate a higher toughness of the seller, contrarily to the assumption underlying the model.

[12] Indeed, negotiations under double auction may be interpreted as a combination of bilateral seller-buyer negotiations and of multilateral seller-seller and buyer-buyer negotiations within each side of the double auction (respectively, the descending one and the ascending one). With this, several of the theoretical features of bilateral and multilateral non-cooperative bargaining models apply (see Attanasi et al. [2015], Gomes [2020], Konrad and Thum [2020] and references therein).

$$p_{Mo} = \sigma \cdot p_{No\text{-}Mo} + (1 - \sigma) \cdot p_{max} \tag{3}$$

Note that σ in Eq. (3) is independent from the order of presentation of market structures in the twelve treatments of Table 2. Indeed, our third assumption models the effect of the order of presentation of market structures. In line with the literature on price anchoring at the beginning of this section, we assume that in each treatment of Table 2 it is the first implemented market structure that acts as anchor on the next four market structures of the timeline. In fact, when making decisions, anchoring is a cognitive bias accounting for the human tendency to rely too heavily on the first piece of information offered (the "anchor"). This initial piece of information biases decision makers' expectations subconsciously. In our design the initial piece of information is represented by (publicly disclosed) trading prices in the three periods of the first implemented market.

This third assumption extends Eq. (3) by providing our model of price anchoring in Eq. (4):

$$p_{Mo} = (\sigma + \mathbb{1}_{\mathbb{A}} \cdot a) \cdot p_{No\text{-}Mo} + (1 - \sigma - \mathbb{1}_{\mathbb{A}} \cdot a) \cdot p_{max} \tag{4}$$

with $a \in [0, 1 - \sigma]$ and indicator function $\mathbb{1}_{\mathbb{A}}$ being equal to 0 in treatments 5, 6, 11 and 12 of Table 2 (where Monopoly is played as first market), and equal to 1 in the remaining eight treatments.[13] In the latter treatments, parameter a accounts for the boosting of the weight of $p_{No\text{-}Mo}$ on p_{Mo}, essentially acting as a constraint on the price a monopolist will feel able to charge to the buyers. More precisely, the average trading price a seller obtains in the non-monopolistic market implemented at the beginning of the treatment anchors the average trading price he can obtain under Monopoly and by Eq. (4) lowers it. In fact, both the monopolist and the buyers in his market has observed those non-monopolistic prices at the beginning of the treatment, where the current monopolist was competing with other three sellers. Hence, once becoming a monopolist, the seller anticipates that his mark-up power is weakened by previous non-monopolistic market trading.

We elaborate two experimental hypotheses in the light of our model of anchoring of Eq. (4). The first hypothesis focuses on monopolistic prices, and especially on whether a seller's monopolistic power is affected by the order through which the market has been implemented.

Hypothesis 4. Monopoly power endures anchoring effect: prices observed under Monopoly in treatments where this is implemented as first market are higher than those observed in treatments where Monopoly is implemented after non-monopolistic markets.

It remains an empirical exploratory question to understand whether the later the implementation of Monopoly in the timeline of Table 2, the more pervasive is the anchoring effect of the first competitive market index. Intuitive reasoning would

[13] In particular, it is *No-Mo*=*Co* in treatments 1-2, *No-Mo*=*Ca* in treatments 3-4, *No-Mo*=*Co-q* in treatments 7-8, and *No-Mo*=*Ca-q* in treatments 9-10. In the four treatments where Monopoly is played as first market, we consider as reference non-monopolistic market for Eq.(4) either the third one or the last one in the sequence of Table 2, depending on the treatment comparisons, as it will become clear in the data analysis of Section 4 (see, e.g., Table 7).

suggest that a longer history of competition should lead to a stronger anchor on future behavior in monopolistic settings. However, lacking extant experimental and empirical evidence on this issue, our model of Eq. (4) is deliberately silent as for the comparison between treatments 1-2, between treatments 3-4, between treatments 7-8, and between treatments 9-10. In each of these pairwise comparisons, Monopoly is implemented as either third or fifth market structure, with the first implemented (non-monopolistic) market being held constant.

The second hypothesis coming from Eq. (4) concerns the ability of monopolists to price-discriminate depending on the order of presentation of this market in the treatment timeline.

Hypothesis 5. Monopolists are able to price-discriminate only when the Monopoly is implemented as first market.

Differently from Hypothesis 4, in our Hypothesis 5 we focus on the dispersion of price distributions. A more disperse distribution of prices is indicative of higher price discrimination under Monopoly. Recall that the predicted behavior in the four non-monopolistic markets leads to convergence to a unique price (see Section 3.1). In this regard, the anchor to previously-implemented non-monopolistic markets is represented by a significantly lower price dispersion.

4 Results

In order to test our predictions, we present the results in two steps. We first study sellers' market-dependent behavior, in line with what discussed in Section 3.1 (Hypothesis 1 through Hypothesis 3).

Secondly, we analyze the effect of price anchoring on monopolists' power, as discussed in Section 3.2, by comparing prices prevailing under Monopoly when this market is played after Perfect Competition, Cartel or both (Hypothesis 4 and Hypothesis 5).[14]

Hypothesis 1. Price-quantity relation. We begin by testing whether average trading prices in monopolistic markets decrease with the monopolist's traded quantity. To do so, we aggregate our data from monopolistic markets, irrespective of their implementation order, and estimate the correlation between prices and quantities. Our data reports a strong negative relation between these two variables (Spearman's $\rho = -0.54$, *p-value*< 0.001). We then extend the same test on the remaining markets. In both Perfect Competition and Cartel markets we find strong evidence of a negative relation (under Perfect Competition: $\rho = -0.10$, *p-value*$= 0.04$; under Cartel: $\rho = -0.11$, *p-value*$= 0.02$). When focusing on markets with quotas, we find that their introduction mitigates the negative relation both under Perfect Competition ($\rho = -0.02$, *p-value*$= 0.74$) and under Cartel ($\rho = -0.09$, *p-value*$= 0.08$). Therefore, our data provides evidence in support of Hypothesis 1. Trading prices are negatively correlated with traded quantity across all markets, and the introduction of quotas mitigates such a relation.

[14]Raw experimental data and all the statistical codes are available from the authors upon request.

Hypothesis 2. Zero-profit trades. We now test whether zero-profit trades are more likely under both perfectly competitive and cartel markets than monopolistic market structures. We compare the proportions of trades closed at a price of 12 across market structures. Our data show that zero-profit trades are more likely under Perfect Competition (proportion test on difference $\pi_{Co} - \pi_{Mo} = 0.14$, *p-value* < 0.001) and Cartel ($\pi_{Ca} - \pi_{Mo} = 0.09$, *p-value*$< 0.001$) than under Monopoly. Furthermore, zero-profit trades are still more likely under both Perfect Competition and Cartel markets even upon the introduction of quotas. Yet, as predicted, the difference relative to Monopoly becomes smaller ($\pi_{Co-q} - \pi_{Mo} = 0.02$, *p-value* $= 0.02$; $\pi_{Ca-q} - \pi_{Mo} = 0.02$, *p-value* $= 0.02$). Therefore, we can conclude that Hypothesis 2 is essentially verified.

Hypothesis 3. Weak monotonicity of prices. To test the monotonicity of prices according to Hypothesis 3, we consider prices of market structures played as first in the treatment timeline of Table 2. For example, we gather prices of perfectly competitive markets from each sequence starting with Perfect Competition (all the Comp markets from sequences CoCaMo, CoMoCa, CoCaMo-q, and CoMoCa-q). Once this is done for all the other markets (i.e. Comp-q, Cartel, Cartel-q, Monopoly), we test inequalities between structures. Table 4 presents the summary statistics of trading prices observed in each of the five market structures played as first in the experiment. Figure 1 shows corresponding price distributions broken down by trading periods. Given that no significant difference is found between Comp and Comp-q (t-test, *p-value*$= 0.588$) and between Cartel and Cartel-q (t-test, *p-value*$= 0.942$), Figure 1 only shows the distribution of trading prices for the three market structures without quotas: Comp, Cartel and Monopoly. Trading prices under Perfect Competition are in line with the theoretical prediction (Figure 1, panel Comp): they are, on average, slightly above the prediction $p^*_{Co} = 13$, and converge to predicted equilibrium level as market interactions approach to the last trading period (see Table B.1 in Appendix B).

The average trading price under Monopoly is lower than the one predicted by the theory in the case of price discrimination (null hypothesis: $p^*_{Mo} = 16$, t-test, *p-value* < 0.01). This result strengthens the evidence of double auction as a trading institution able to control over monopoly power (Smith and Williams [1989]). Furthermore, the average monopolistic price is lower than predicted since the very first period (Figure 1, panel Monopoly), and then slightly declines, although not significantly, in trading periods 2-3 (Table B.1; $p_{Mo|t=1} = 14.81$, $p_{Mo|t=3} = 14.50$).

By looking at Figure 1 (panel Cartel), one can notice that the average Cartel price in period 1 is closer to the theoretical prediction of maintained Cartel agreement ($p_{Ca|t=1} = 15.42$). It then shifts towards the competitive equilibrium price in subsequent periods, especially in period 3 ($p_{Ca|t=3} = 13.56$). In line with our predictions, it thus emerges that although sellers reach a mutual agreement on a (higher) trading price in the first period, they are not able to maintain it (Huck et al. [2001]).

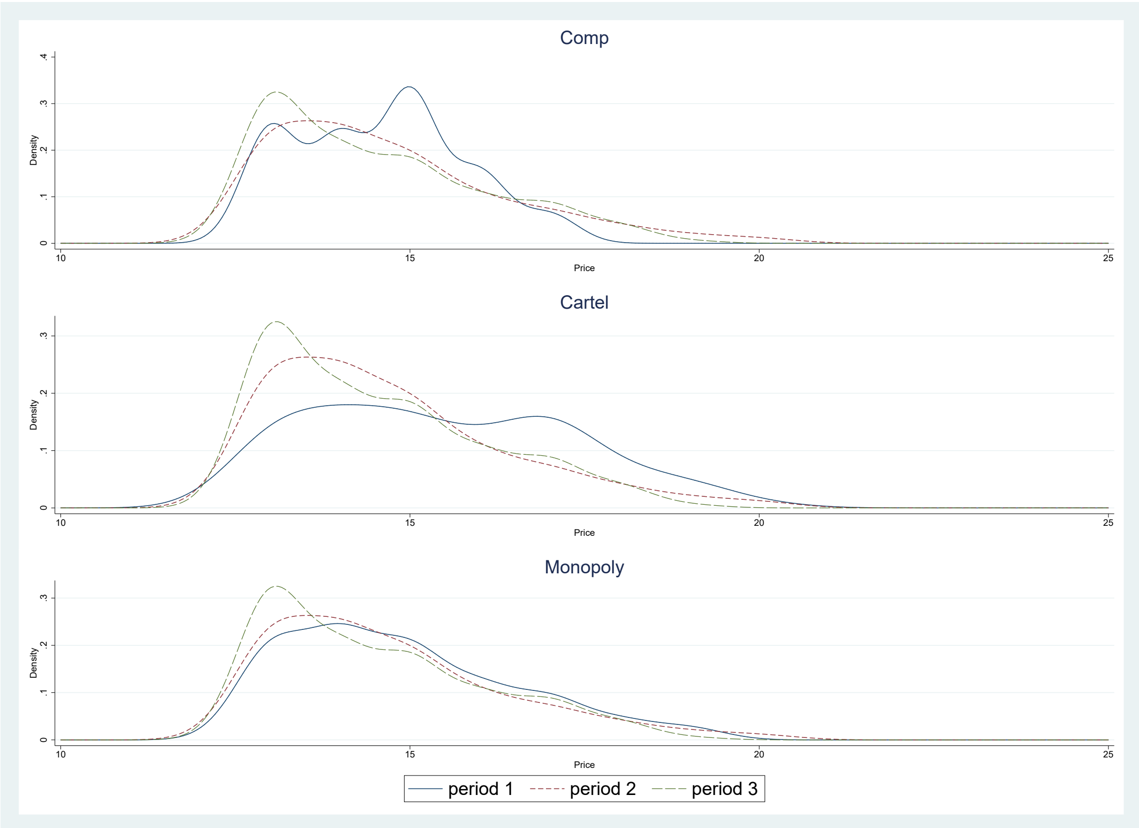
To further investigate differences across periods and the learning effects, we run several regression models including all treatment dummies as well as period controls (Table 5).[15] We regress the observed trading prices on market struc-

[15] Recall that sellers face the same marginal cost c (see Section 2.1). Thus, all sellers have the same reservation price, which is why we do not include it in the regression models as a control.

Table 4: Summary statistics of trading prices for market structures played as first (pooled across the three trading periods)

	p_{Co}	p_{Co-q}	p_{Ca}	p_{Ca-q}	p_{Mo}
Mean	14.00	13.81	14.36	14.32	14.63
Max	20	18	20	19	20
Min	12	12	12	12	12
St. dev.	1.28	1.09	1.65	1.24	1.70
N (trades)	275	284	277	261	444

Figure 1: Distribution of trading prices broken down by periods in Perfect Competition, Cartel and Monopoly when played as first



Note: Density distributions using kernel estimator.

ture fixed effects, considering Monopoly as a benchmark.[16] Coefficients of all fixed effects associated with perfectly competitive markets (Co and Co-q) in Model 1 are negative and significant at any conventional level. Prices under Perfect Competition are on average lower than under Monopoly of about -0.628 (*p-value*< 0.05). Similar results are reported when comparing with-quota competitive markets to Monopoly

[16] To address potential issues due to the number of clusters in our data (36 clusters at the session level, see Table 2) as well as to account for the hierarchical nature of the data, we also run mixed-effects models, as recommended by Moffatt [2015]. Results reported are similar across all model specifications. Mixed-effects models in Table B.2 of Appendix B validate the robustness of results from our clustered-error models in Table 5.

(−0.818, *p-value*< 0.01). While in Cartel markets (both with and without quotas) average prices are on average lower than those prevailing under Monopoly, these differences are not significant, consistently to what reported above in Table 4 (−0.296, *p-value*= 0.184 for Cartel; −0.313, *p-value*= 0.202 for Cartel with quotas).

Table 5: Regression models of prices from markets implemented as first in each sequence

	(1) Price	(2) Price	(3) Price$\|t$=1	(4) Price$\|t$=2	(5) Price$\|t$=3
Co	-0.628*	-0.632*	-0.317	-0.505	-0.998***
	(-2.21)	(-2.18)	(-0.96)	(-1.32)	(-3.96)
Co-q	-0.818**	-0.850**	-0.695*	-0.830*	-0.961**
	(-2.87)	(-2.98)	(-2.32)	(-2.38)	(-3.26)
Ca	-0.296	-0.320	0.616	-0.529*	-0.945***
	(-1.34)	(-1.42)	(1.76)	(-2.22)	(-4.70)
Ca-q	-0.313	-0.325	0.164	-0.318	-0.734***
	(-1.29)	(-1.31)	(0.49)	(-0.95)	(-3.73)
Period 2		-0.547***			
		(-5.13)			
Period 3		-0.911***			
		(-7.43)			
Constant	14.63***	15.15***	14.81***	14.61***	14.50***
	(89.00)	(80.85)	(73.32)	(76.16)	(87.80)
N (trades)	1542	1542	478	516	548

Notes: OLS model with errors clustered at the session level.
t-test in parentheses. * *p-value*< 0.05, ** *p-value*< 0.01, *** *p-value*< 0.001.

Furthermore, we control for possible trends along the three trading periods, by including the variables Period 2 and Period 3 (Model 2). Such variables control for possible trends throughout trading periods 1 to 3 of each market. As a result, the differences between Monopoly and all perfectly competitive market structures yet remain significant upon the inclusion of such fixed effects. Lastly, consistently with what discussed at the beginning of this section, overall prices decrease over periods as tradings unravel (estimates associated with Period 2 equal to −0.547, Period 3 equal to −0.911, *p-value* < 0.001). As a confirmation, when analyzing prices separately in each period, we find that all market structures display similar prices in the first period (Model 3) with the exception of Perfect Competition with quotas (prices lower on average of about −0.695, *p-value* < 0.05). However, as market tradings unfold, the price difference between Monopoly and any other market widens (Models 4-5), becoming highly significant in the last period (magnitude ranging from −0.734 to −0.998). Finally, we report no significant evidence of difference between estimates associated with Cartel (*Ca, Ca-q*) and Perfect Competition (*Co, Co-q*) in Model 5 as well as in the other models.[17]

In line with subjects' learning toward the equilibrium, it follows that, when looking at prices prevailing in the last trading period, our results provide evidence in support of Hypothesis 3 of weak monotonicity:

$$p_{Co} = p_{Co-q} = p_{Ca} = p_{Ca-q} < p_{Mo} \tag{5}$$

Further evidence supporting our learning approach is shown in Table B.3 of Appendix B, reporting the results on intramarginal inefficiency across markets. In fact, the fraction of sellers and buyers not trading in a given period both decrease as periods unfold, in all markets but Perfect Competition. Intramarginal inefficiency decreases from period 1 to period 3 when pooling all market structures, both in terms of sellers not trading and in terms of buyers not trading within a period (for sellers: 4.31% vs. 2.64% in periods 1 vs. 3, yet the difference between the two negligible fractions is not significant, *p-value*=0.24; for buyers: 24.75% vs. 22.06% in periods 1 vs. 3, *p-value*= 0.079; Wilcoxon-signed rank test). These results highlight the learning and efficiency properties of the double-auction trading mechanism.

Hypothesis 4. Anchoring effect on Monopoly – Spillovers of previous markets on Monopoly. We now pass on investigating whether monopolistic prices are affected by the formation of price anchors in previously-implemented market structures. To do so, we provide evidence of anchoring effects at both market and individual level. The market-level analysis compares prices from all Monopolies played in the first position (MoCoCa, MoCaCo, MoCoCa-q, and MoCaCo-q) to those played in the middle (CoMoCa, CaMoCo, CoMoCa-q, and CaMoCo-q) or at the end (CoCaMo, CaCoMo, CoCaMo-q, and CaCoMo-q) of the treatment timelines of Table 2.

Table 6 reports the results of regression models on trading prices under Monopoly, varying for the order of implementation and for the type of this order (i.e., after Competition or after Cartel, if Monopoly is played in the middle of the treatment; after Competition and then Cartel or after Cartel and then Competition, if it is played at the end of the treatment timeline of Table 2).[18] We consider four dummy variables, i.e., one for each of these order-type combinations of implementation, with Monopoly played as first market as reference for comparisons. Models 1-2 report that monopolistic prices endure the effect of previously-played markets, irrespective of the inclusion of fixed effects Period 2 and Period 3 to control for time trends.

When comparing anchoring effects on Monopoly implemented as third structure, the highest negative impact on monopolistic prices is found when Monopoly is played in the middle of the treatment after Perfect Competition (trading prices are lower of about 0.95 points). A lower but still significant negative effect is found when Monopoly is played in the middle of the treatment after Cartel (trading prices are lower of about 0.78 points). However, we report no significant difference between

[17]Tests on parameters equality display all *p-values* being higher than any conventional level. Results are available upon request.

[18] To address potential issues with clustering errors at the session level and given the hierarchical nature of the data, we report in Table B.4 of Appendix B the results from the corresponding mixed-effects models.

the effect of these two markets (Model 1, $Co = -0.938$ vs. $Ca = -0.772$, F-test of the difference, *p-value* $= 0.317$).

When Monopoly is introduced at the end of the treatment, we find similar results irrespective of the market order that precedes it. Indeed, while variable $CaCo$ has a higher negative effect relative to $CoCa$ in all model specifications except Model 3, this difference is not significant (lowest *p-value* $= 0.206$ in Model 1, F-test of the difference $CaCo = -0.812$ vs. $CoCa = -0.648$). All results remain unchanged when analyzing data disentangled by period (Models 3-5). The same picture emerges when relying on the estimates from the mixed-effects models of Table B.4 (Co vs. Ca: $\chi^2(1) = 0.09$, *p-value*$= 0.77$; $CoCa$ vs. $CaCo$: $\chi^2(1) = 0.24$, *p-value*$= 0.63$).

Table 6: Regression models of Monopoly prices after any other market structures

	(1)	(2)	(3)	(4)	(5)
	Mo Price	*Mo* Price	*Mo* Price$\|t$=1	*Mo* Price$\|t$=2	*Mo* Price$\|t$=3
Co	-0.938***	-0.949***	-1.136***	-0.782**	-0.927***
	(-4.80)	(-4.83)	(-4.81)	(-3.05)	(-4.21)
Ca	-0.772***	-0.781***	-0.650*	-0.725**	-0.955***
	(-3.73)	(-3.76)	(-2.46)	(-2.95)	(-4.71)
CoCa	-0.648**	-0.659**	-0.714**	-0.627*	-0.632**
	(-3.00)	(-3.04)	(-2.77)	(-2.27)	(-2.84)
CaCo	-0.812***	-0.821***	-0.650*	-0.906***	-0.901***
	(-3.85)	(-3.86)	(-2.36)	(-3.78)	(-4.07)
Period 2		-0.175***			
		(-2.41)			
Period 3		-0.355***			
		(-4.38)			
Constant	14.63***	14.82***	14.81***	14.61***	14.50***
	(89.31)	(85.04)	(73.58)	(76.40)	(88.09)
N (trades)	1501	1501	478	495	528

Notes: OLS model with clustered errors at the session level.
t-test in parentheses. * *p-value* < 0.05, ** *p-value* < 0.01, *** *p-value* < 0.001.

Lastly, we provide evidence for the comparison between monopolistic structures that are implemented in the middle vis-à-vis those implemented as last in a given sequence. By comparing estimates Co and $CoCa$ appearing in Table 6, we report no significant evidence of a statistical difference ($F(1, 143) = 2.71$, *p-value*$= 0.102$); similar results are obtained when comparing Ca and $CaCo$ ($F(1, 143) = 0.05$, $p-value = 0.827$). Results are similar also when considering estimates from the models reported in Table B.4 (Co vs. $CoCa$: $\chi^2(1) = 0.75$, *p-value* $= 0.386$; Ca vs. $CaCo$: $\chi^2(1) = 0.000$, *p-value*$= 0.947$).

On top of providing market-level evidence showing how Monopoly power endures the effect of price anchoring due to previously-implemented market structures, we now look closer at sellers' behavior at the individual level.

We start by investigating how prices have changed for given sellers when they play a Monopoly after a sequence of competitive or cartel market structures. To do so, we consider treatments of Table 2 where Monopoly is implemented as third or fifth market. For example, in *CoMoCa*, subjects have played first two competitive markets (without and with quotas) and then played under Monopoly before ending the session with two cartel markets. We call these sequences of markets as the *anchor-sequences*, including sequences where Monopoly is implemented as fifth market. Considering only these sequences, we calculate the difference in each seller's average price between firstly-implemented non-monopolistic markets and later-implemented Monopoly (δ_a in Table 7). Consistently with our previous analyses (Table 6) and our theoretical framework (Section 3.2, Eq. (4)), we expect that sellers adjust Monopoly prices downwards after having experienced non-monopolistic market structures.[19] The results reported in the left panels of Table 7 (column δ_a) show that individual price changes are even negative almost all the anchor-sequences, with monopolistic prices being often lower than prices prevailing in the first implemented market structure. Indeed, later implementation of Monopoly seems to make sellers lose their mark-up power entirely, irrespective of whether it is implemented as third structure in the sequence (Table 7, upper panel) or as fifth one (Table 7, lower panel).

Obviously, not all the difference δ_a is due to the anchor effect a of Eq. (4), as it should be clear by comparing Eq. (4) with Eq. (3) of our model. To isolate the anchor effect from possible confounders (e.g., the correlation σ between non-monopolistic and monopolistic behavior at the seller's level), we construct a control difference that we compare with δ_a. In particular, we consider market sequences in which Monopoly is implemented as the first market structure (*control-sequences*, hereafter) and calculate the difference between the prices under Monopoly and under the market that comes later in the sequence (δ_c in Table 7). The results reported in the right panels of Table 7 (column δ_c) show that monopolistic prices are always higher than prices prevailing in later-implemented market structures, regardless of considering the third market structure (upper panel) or the fifth market structure (lower panel) in the treatment timeline.

We then match control-sequences with anchor-sequences so that the first and the third (resp., fifth) implemented markets are switched in the upper (resp., lower) panel of Table 7. For example, we match CoMoCa with MoCoCa-q in the upper panel (Monopoly played as third structure), CoCaMo with MoCaCo-q in the lower panel (Monopoly played as fifth structure), etc. Notice that we use control-sequences as a counterfactual to test if there is a substantial difference relative to the associated anchor-sequence. This approach consists of a between-subjects comparison of within-subjects differences. Results in the last column of Table 7 (Δ_{a-c}) display a negative and significant difference between the two mark-up δ_a and δ_c in all of the eight pairwise comparisons. This evidence confirms that monopolistic prices are lowered when non-monopolistic markets are played before Monopoly, regardless of the type of these markets (Comp, Comp-q, Cartel, or Cartel-q).

[19] As discussed in our theoretical section, in testing our Hypothesis 4, we did not consider comparisons between monopolies that are implemented as third vs. last structure. Our model is silent as to comparisons between monopolies that incorporate already an anchoring effect. We restrain our attention to the clean comparison between anchoring sequences and control sequences.

Table 7: Average price differences between consecutive markets

Monopoly played as third structure

Anchor	δ_a	*Control*	δ_c	Δ_{a-c}
CoMoCa	$p_{Mo} - p_{Co} = -0.21$	MoCoCa-q	$p_{Mo} - p_{Co} = 0.01$	-0.22^{+}
CoMoCa-q	$p_{Mo} - p_{Co-q} = -0.16$	MoCoCa	$p_{Mo} - p_{Co-q} = 2.52$	-2.68***
CaMoCo	$p_{Mo} - p_{Ca} = -0.18$	MoCaCo-q	$p_{Mo} - p_{Ca} = 1.76$	-1.94***
CaMoCo-q	$p_{Mo} - p_{Ca-q} = -0.96$	MoCaCo	$p_{Mo} - p_{Ca-q} = 1.34$	-2.30***

Monopoly played as fifth structure

Anchor	δ_a	*Control*	δ_c	Δ_{a-c}
CoCaMo	$p_{Mo} - p_{Co} = -0.11$	MoCaCo-q	$p_{Mo} - p_{Co} = 2.23$	-2.34***
CoCaMo-q	$p_{Mo} - p_{Co-q} = 0.68$	MoCaCo	$p_{Mo} - p_{Co-q} = 1.97$	-1.29***
CaCoMo	$p_{Mo} - p_{Ca} = -0.21$	MoCoCa-q	$p_{Mo} - p_{Ca} = 0.22$	-0.43***
CaCoMo-q	$p_{Mo} - p_{Ca-q} = -0.60$	MoCoCa	$p_{Mo} - p_{Ca-q} = 2.21$	-2.81***

Notes: The difference $\Delta_{a-c} = \delta_a - \delta_c$. Mann-Whitney tests: $^{+}$ *p-value* < 0.10, * *p-value* < 0.05, ** *p-value* < 0.01, *** *p-value* < 0.001.

Finally, we move to the study of sellers' toughness. As shown in Section 3.2, we derive a model of price anchoring in which the prices prevailing in previous markets affects sellers' perceived monopoly power – i.e., their bargaining toughness (Kristensen and Gärling [1997], Attanasi et al. [2016]). By exploiting our within-subjects design, we perform a second kind of analysis to estimate an indicator of sellers' toughness as the weight in a convex linear combination of two market prices, in line with the formalization of Eq. (3). Drawing on Eq. (4) and rearranging it, we can express a sellers' average trading price under Monopoly as a function of his average trading price in non-monopolistic markets, depending on the sequence:

$$\begin{cases} \sigma + a = \dfrac{p_{max} - p_{Mo}}{p_{max} - p_{No\text{-}Mo}}, & \text{if anchor sequence} \\ \sigma = \dfrac{p_{max} - p_{Mo}}{p_{max} - p_{No\text{-}Mo}}, & \text{if control sequence} \end{cases} \tag{6}$$

Based on this equation, we calculate the values of $\sigma + a$ and σ algebraically by considering different sequences of market structures. For each seller, $\sigma+a$ is obtained from anchor-sequences (as in Table 7) as the ratio between the distances from the highest possible trading price p_{max} of the average trading price under Monopoly and under the first-implemented non-monopolistic market. The same calculation is performed for σ in control sequences, by considering prices from Monopoly and third- (or fifth-) implemented non-monopolistic markets (as in Table 7). Table 8 reports the average values of our parameters of interest. Consistently with our previous analysis, we compare anchor-sequences with control-sequences and test if the difference between $\sigma + a$ in anchor-sequences and σ in control-sequences is significantly greater than zero (using Mann-Whitney tests).

The results reported in Table 8 can be interpreted in a straightforward way. A

Table 8: Estimates of σ and a using anchor and control sequences

Monopoly played as third structure				
Anchor	CoMoCa	CoMoCa-q	CaMoCo	CaMoCo-q
$\sigma + a$	0.96	0.93	0.94	0.97
Control	MoCoCa-q	MoCoCa	MoCaCo-q	MoCaCo
σ	0.93	0.61	0.73	0.80
Difference (a)	0.03^{+}	0.32^{***}	0.21^{***}	0.17^{***}

Monopoly played as fifth structure				
Anchor	CoCaMo	CoCaMo-q	CaCoMo	CaCoMo-q
$\sigma + a$	0.91	0.88	0.93	0.98
Control	MoCaCo-q	MoCaCo	MoCoCa-q	MoCoCa
σ	0.69	0.71	0.92	0.65
Difference (a)	0.22^{***}	0.17^{***}	0.01^{*}	0.33^{***}

Note: Difference (a) reports the estimates of a and the results of Mann-Whitney tests; $^{+}$ *p-value* < 0.10 * *p-value* < 0.05, ** *p-value* < 0.01, *** *p-value* < 0.001.

value of $\sigma + a = 0.96$ (first row, first column of the upper panel) shows that, on average, sellers in the sequence CoMoCa heavily anchor to prices carried out in competitive markets when charging Monopoly prices later on in the sequence. A high value of σ (0.93) reflects a strong tendency of sellers to offer prices that are very similar to third- (or fifth-) implemented structures. The difference between these two estimates (i.e., $a = 0.03$), is a proxy of the extent to which Monopoly endures the anchoring effect. Results from our data support our hypothesis across all market sequences. Prices in later-implemented monopolistic structures strongly depend on sellers' toughness established in previously-implemented markets. Indeed, estimates of a are significantly positive in all of the eight pairwise comparisons. Sellers tend to anchor their offers to prices of deals carried out in previously-implemented markets ($p_{No\text{-}Mo}$ in Eq. (6)).

We find mixed evidence on the effect of a longer history of competition on anchoring a. The average estimate of a is the same between sequences in which Monopoly is implemented as third structure and those in which it is implemented as fifth one (0.16 vs. 0.15, *p-value*=0.88; Mann-Whitney test).[20] We can finally conclude that our twofold evidence (at the market and seller level) supports Hypothesis 4, by suggesting that monopolists' power endures the negative effect of price anchoring formed in previous non-monopolistic market structures.

[20]Replicating the difference-in-difference-like analysis of Table 7 for treatment comparisons between sequences with Monopoly implemented as third vs. fifth market structure, we confirm the non-significant differences detected above by contrasting estimates of parameters in the regression models of Table 6 and Table B.4. Results are available from the authors upon request.

Hypothesis 5. Price discrimination in Monopoly. We finally focus on the ability of monopolists to discriminate among buyers with different maximum willingness to pay. Recall that in the test of Hypothesis 1 we find that, when Monopoly is played as first market structure in a treatment, monopolists set on average lower prices than those theoretically predicted in the case of price discrimination (see Table 3 and Figure 1). However, here we aim at studying differences in price dispersion under Monopoly according to the order-type combinations of its implementation in the treatment sequence.

Figure 2 depicts the distribution of monopolistic prices according to the fact that, in the treatment timeline of Table 2, Monopoly is introduced as first market (panel (a)), as third market after Perfect Competition (panel (b)), as third market after Cartel (panel (c)), or at the end of the sequence, after both these markets, independently of their order (panel (d)).

Figure 2: Per-period density plots of Monopoly prices

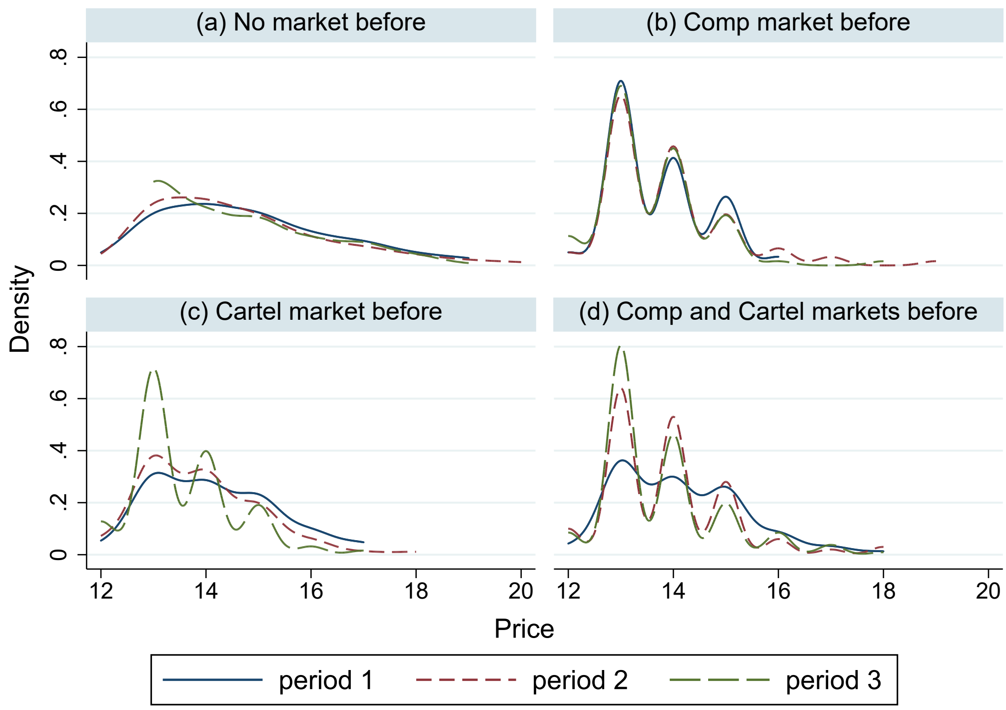


Figure 2 shows that when Monopoly is played as first market, sellers are able to implement price discrimination among buyers. In fact, most of the prices $p > c = 12$ that could be afforded by the buyers given their budget constraint ($p \in \{13, 14, ..., 19\}$), are actually paid (see panel (a) of Figure 2). When Monopoly is played after some other market structures, price discrimination becomes less obvious, especially in the second and third trading periods. That is, when buyers and sellers go through Perfect Competition, Cartel or both of them before being exposed to Monopoly, sellers – finally becoming monopolists – are much less able to exploit their market power.

In order to confirm these results, Table 9 reports the by-period difference in price variances between monopolistic structures played as first and every other monopolistic market (that is $\Delta(\varsigma)$). If price discrimination is favored when Monopoly is played at the beginning of a treatment, we should observe a higher variance difference.

Table 9: Differences of variances in Monopoly prices between monopolies implemented at the beginning of a treatment or later, varying previously-implemented markets

	Variance difference			
Price	$t = 1$	$t = 2$	$t = 3$	Overall
$\Delta(\varsigma_{CoMo})$	1.96***	2.20***	1.43***	1.93***
$\Delta(\varsigma_{CaMo})$	1.29***	2.27***	1.43***	1.60***
$\Delta(\varsigma_{CoCaMo})$ and $\Delta(\varsigma_{CaCoMo})$	1.30***	2.23***	1.16***	1.53***

Notes: Δ reports the difference between the variance of p_{Mo} when Monopoly is played as first and when it is played after non-monopolistic market structures. Levene's test on the difference Δ. * *p-value* < 0.05, ** *p-value* < 0.01, *** *p-value* < 0.001.

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Pairwise-parametric tests on the variance of monopolistic price distributions show that trading prices under Monopoly played as first market have higher variance than under Monopoly played after any possible sequence of other market structures. All $\Delta(\varsigma)$ reported in Table 9 are positive and different from zero (Levene's test, *p-value* < 0.01 in every case). Similar results also hold when we compare monopolistic structures within each period: prices prevailing under Monopoly played as first market display higher variance than the prices observed in any other later implemented monopolistic structures for each of the three trading periods considered separately (pairwise Levene's test, *p-value* < 0.001 in all the cases).

5 Conclusions

In this paper, we analyze different market structures with few sellers and many buyers, under the same trading institution: double auction. The paper contributes to the literature on trading mechanisms in general, and double auction in particular, by incorporating behavioral aspects that are not accounted for in standard models and testing behavioral-theory driven predictions through a laboratory experiment. In this regard, our contribution is threefold.

First of all, we strengthen previous experimental evidence showing that double-auction trading mechanisms can recreate perfectly competitive environments (Smith and Williams [1989, 1981], Davis and Williams [1991]). Indeed, prices prevailing in our perfectly competitive markets converge towards predicted equilibrium levels, despite the fact that the fraction of buyers in the market is six times the fraction of sellers. Similarly, when cartel opportunities are open to sellers, they do not reach mutual agreement on prices, consistently with previous experimental literature (Huck et al. [2001]).

Second, while there is evidence in the extant experimental literature showing that double-auction trading mechanisms cannot control over monopoly power (Muller et al. [2002], Ledyard and Szakaly-Moore [1994], Brown-Kruse et al. [1995], Godby [2002]), we provide evidence showing that monopoly power can be significantly resized under double-auction institutions. In fact, trading prices under monopoly are significantly lower than those predicted by the theory: double-auction trading institutions succeed in preventing monopolists to fully extract buyers' maximum willingness to pay.

Our third and most important finding concerns spillovers of previous market trading on prices prevailing in monopolistic markets. Monopolists' power is sensitive to past trading experience and to the formation of price anchoring in previous (more competitive) market structures. Market spillovers play a fundamental role in weakening monopolists' ability to price discriminate in our double-auction setting. In fact, when a monopolistic market is not preceded by any other market structure, price discrimination seems more effective. However, perfectly competitive markets, as well as cartel structures, reduce the possibility of price discrimination in later-played monopolies. In other words, prices formed under perfect competition or through non-binding cartel agreements permeate buyers and sellers' behavior in later-played monopolies, with the result being that monopolists are less likely to price discriminate. Furthermore, the influence of initial non-monopolistic trading prices on a later-played monopoly is invariant to the timing of implementation of this monopoly at a later stage.

Our research also contributes to the growing body of literature dealing with experimental methods by highlighting the relevance of order effects in experiments on trading mechanisms. Recall, however, that our findings rely on a series of classroom experiments without monetary rewards, as it is common practice when trying to replicate textbook and theoretical predictions (see, e.g., Holt [1996, 1999], and Finley et al. [2019]). Despite our experimental recommendation for subjects to earn a positive profit for each traded unit, we acknowledge that designing an incentive-compatible experiment (e.g., by paying sellers and buyers according to their profits in the experiment) might mitigate or boost the impact of the order effects detected in our study. Indeed, this seems to be a quite intriguing issue. On the one hand, monetary incentives might lead sellers' behavior to better adhere to market rules, with monopolists extracting all buyers' surplus up to 1 point of profit left to each intramarginal buyer. This would happen despite sellers' perception of a reduced market power due to previous participation in more competitive markets. On the other side, the impact of order effects might be boosted by monetary incentives. In fact, due to role asymmetry, social preferences as inequity aversion might emerge, leading buyers to reject those monopolists' offers that leave buyers with only 1 point of profit, consistently with evidence from ultimatum games (see Güth et al. [1982], and a plethora of follow-up studies). More precisely, the more buyers learn that sellers trade at substantially lower prices under previous markets, the less willing they are to bear perfect discrimination under monopoly – which they (have learned to) perceive as unfair. Furthermore, the latter effect would depend on the specific payment rule implemented to introduce monetary incentives (see Cox et al. [2015] and Charness et al. [2016]). In fact, randomly paying only one market structure at the end of the experiment could eventually boost order effects when monopoly is played as last market. We leave for future research the issue on the interaction between order effects and monetary incentives in experiments on trading mechanisms.

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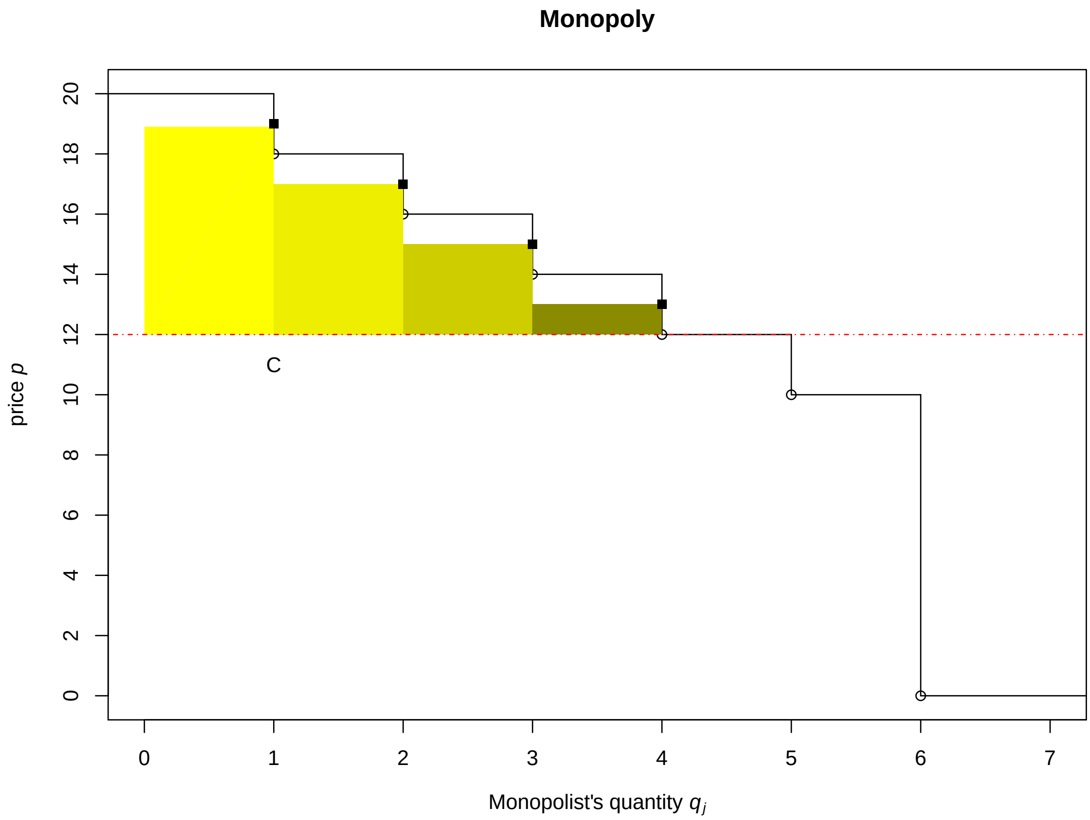
Appendix

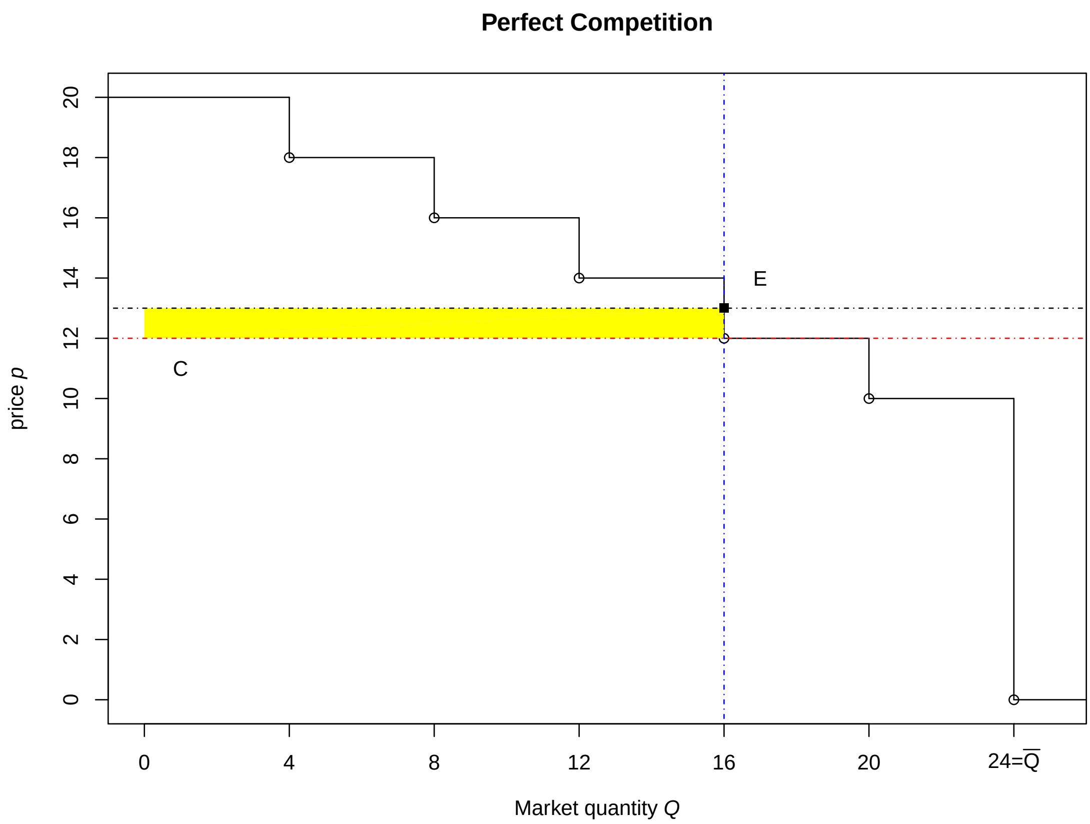
A Supplementary Figures

Figure A.1: Demand and Cost functions under Monopoly



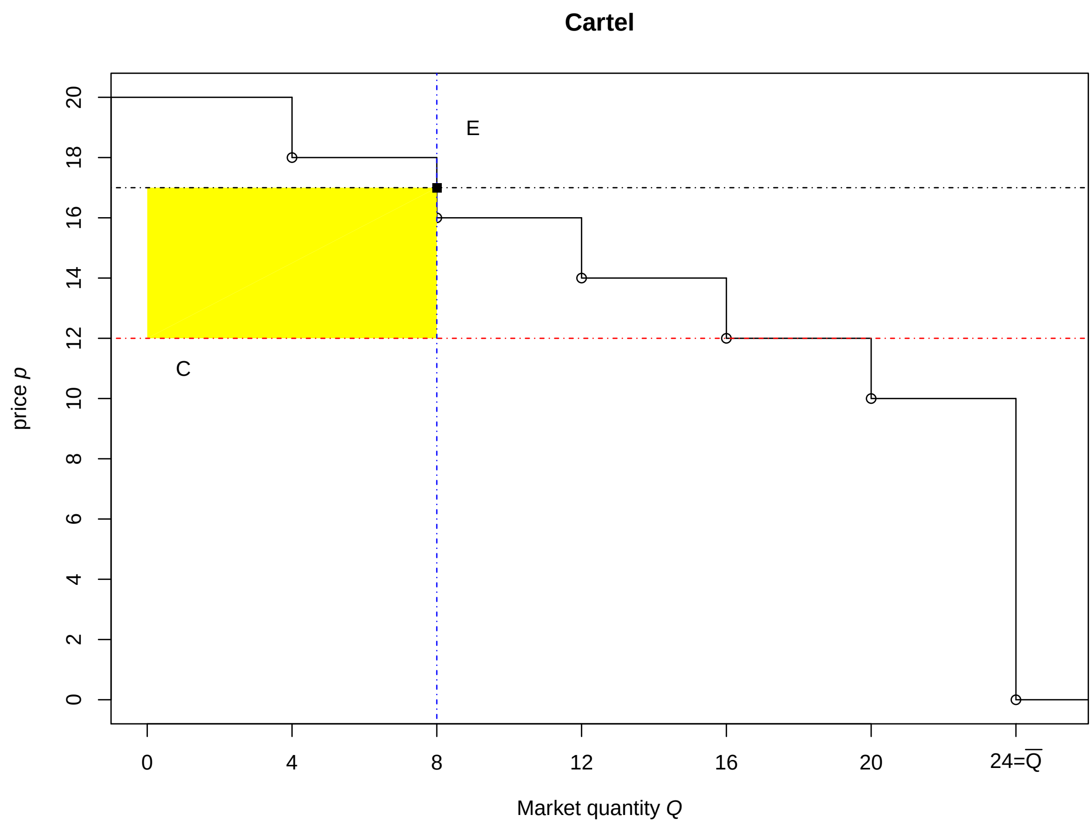
Note: the sum of colored areas represents monopolist j's surplus ($j = 1, 2, 3, 4$).

Figure A.2: Demand and Cost functions under Perfect Competition



Note: the yellow area represents the sellers' surplus.

Figure A.3: Demand and Cost functions under Cartel



Note: the yellow area represents the sellers' surplus.

Figure A.4: Example of a seller's computer screen during the experiment.

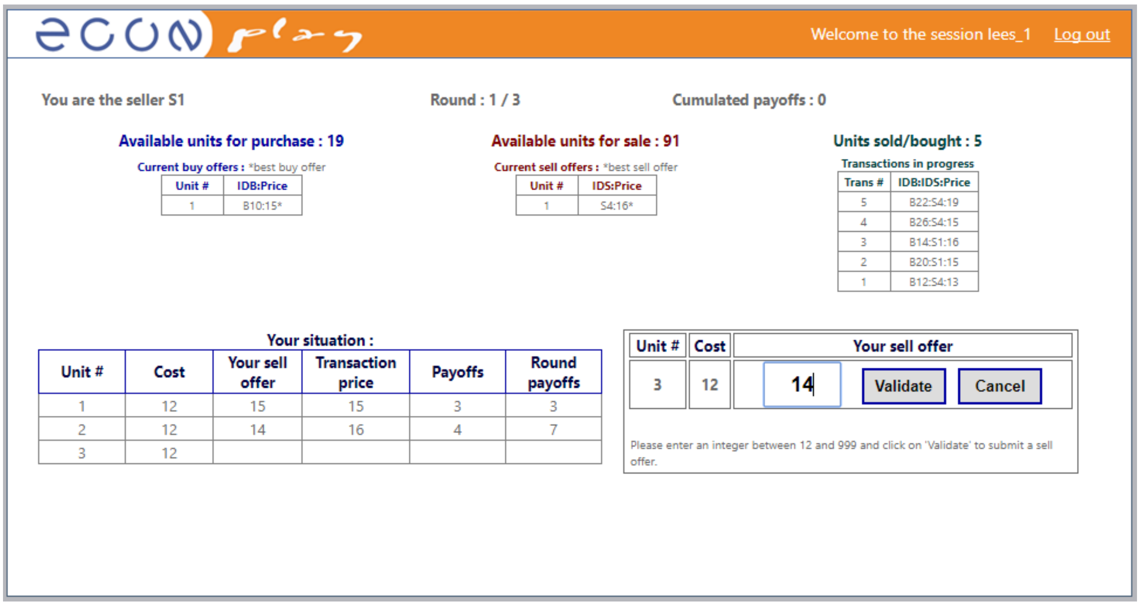
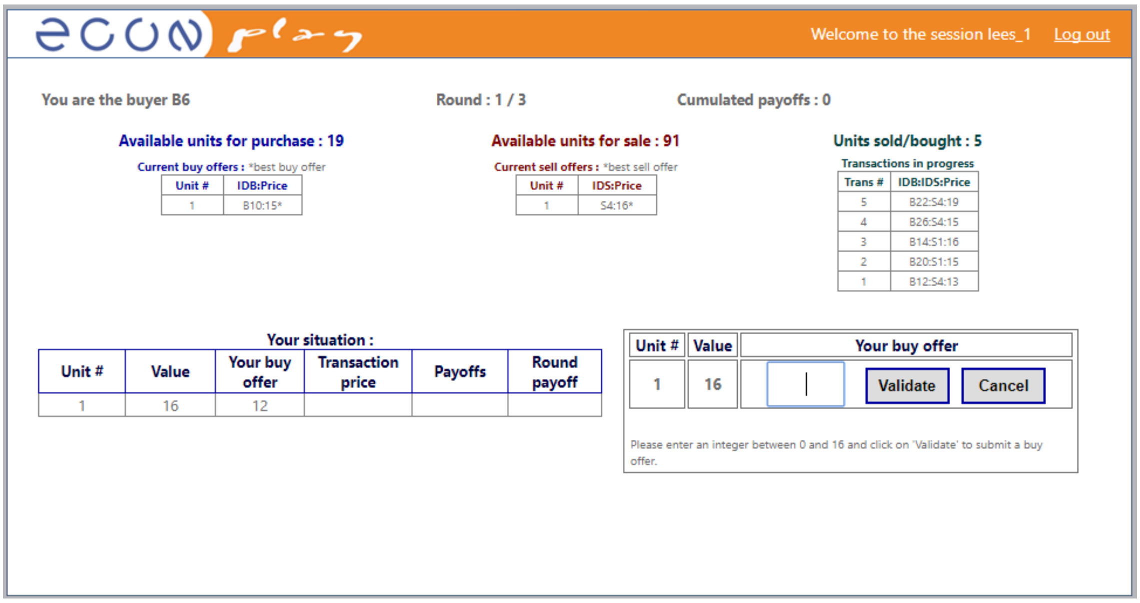


Figure A.5: Example of a buyer's computer screen during the experiment.



B Supplementary Tables

Table B.1: Average trading prices for market structures played as first, disentangled by trading period $t = 1, 2, 3$

	p_{Co}	p_{Co-q}	p_{Ca}	p_{Ca-q}	p_{Mo}
$t = 1$	14.49	14.12	14.42	14.97	14.81
$t = 2$	14.10	13.78	14.08	14.30	14.61
$t = 3$	13.50	13.54	13.56	13.76	14.50

Table B.2: Regression models of prices from markets implemented as first in each sequence

	(1) Price	(2) Price	(3) Price|t=1	(4) Price|t=2	(5) Price|t=3
Comp	-0.742^{+}	-0.765^{+}	-0.379	-0.609	-1.121**
	(-1.71)	(-1.70)	(-0.90)	(-1.07)	(-2.88)
Comp-q	-0.945*	-0.990*	-0.797^{+}	-0.886	-1.048**
	(-2.18)	(-2.21)	(-1.91)	(-1.56)	(-2.69)
Cartel	-0.410	-0.459	0.563	-0.619	-1.077**
	(-0.95)	(-1.02)	(1.34)	(-1.09)	(-2.76)
Cartel-q	-0.451	-0.478	0.105	-0.392	-0.865*
	(-1.04)	(-1.07)	(0.25)	(-0.69)	(-2.21)
Period 2		-0.579***			
		(-7.67)			
Period 3		-0.952***			
		(-12.74)			
Constant	14.78***	15.734***	14.94***	14.70***	14.63***
	(94.52)	(92.37)	(83.67)	(70.31)	(99.76)
N (trades)	1542	1542	478	516	548

Notes: Mixed-effect regression models. Random effects at the session, market and seller levels. t-test in parentheses. * *p-value* < 0.05, ** *p-value* < 0.01, *** *p-value* < 0.001.

Table B.3: Fractions of intramarginal sellers and buyers that do not trade, across markets

Market	Sellers $t=1$	Sellers $t=2$	Sellers $t=3$	Buyers $t=1$	Buyers $t=2$	Buyers $t=3$
Comp	4.17%	6.25%	5.56%	20.42%	20.00%	20.97%
Comp-q	2.78%	2.08%	1.39%	21.11%	23.61%	20.42%
Cartel	4.17%	9.03%	4.17%	22.08%	23.75%	20.00%
Cartel-q	8.33%	3.47%	1.39%	26.53%	26.39%	22.22%
Monopoly	2.08%	2.08%	0.69%	33.61%	31.25%	26.67%
Average	4.31%	4.58%	2.64%	24.75%	25.00%	22.06%

Table B.4: Regression models of Monopoly prices after any other market structures

	(1) *Mo* Price	(2) *Mo* Price	(3) *Mo* Price$\|t$=1	(4) *Mo* Price$\|t$=2	(5) *Mo* Price$\|t$=3
Co	-1.000**	-1.016**	-1.269***	-0.856*	-0.961***
	(-3.26)	(-3.27)	(-4.07)	(-2.31)	(-3.34)
Ca	-0.896**	-0.911**	-0.758*	-0.791*	-1.038***
	(-2.92)	(-2.94)	(-2.45)	(-2.14)	(-3.62)
CoCa	-0.693*	-0.711*	-0.769*	-0.698	-0.639*
	(-2.25)	(-2.29)	(-2.46)	(-1.85)	(-2.21)
CaCo	-0.873**	-0.886**	-0.715*	-0.899*	-0.978***
	(-2.84)	(-2.85)	(-2.30)	(-2.43)	(-3.41)
Period 2		-0.219***			
		(-3.29)			
Period 3		-0.403***			
		(-6.14)			
Constant	14.78***	15.01***	14.97***	14.71***	14.62***
	(82.90)	(81.19)	(80.90)	(67.96)	(87.35)
N (trades)	1501	1501	478	495	528

Notes: Mixed-effects regression models. Random effects at the session, market and seller levels. t-test in parentheses. + *p-value* < 0.10, * *p-value* < 0.05, ** *p-value* < 0.01, *** *p-value* < 0.001.

C Instructions

[*Translated from French to English; Treatment 1: CoCaMo (see Table 2)*]

The goal of this experiment is to introduce the concepts of monopoly and cartel to students.

General instructions

The experiment consists of 5 consecutive phases. In each of them, there are 4 sellers and 24 buyers of a fictitious good. At the beginning of the experiment the computer will inform you if you are assigned to the role of a seller or a buyer. You will keep the same role throughout the whole experiment.

If you are a seller, you can make profits by selling a unit of the good to a buyer. On your screen, the cost of production of each unit of the good will be displayed. If you sell one unit of at a price P and the production cost of this unit is C, your profit for this unit will be equal to the difference P – C.

If you do not sell any unit of the good, your profit will be zero. You are not obliged to sell. For example, it can be that the price that has been proposed to you for one unit does not cover the production cost. In this case, you will not be able to sell that unit. Furthermore, although the software allows you to sell one unit at the production cost, we recommend you to make at least 1 point of profit for each sold unit.

If you are a buyer, you can buy a unit of the good from a seller. Your valuation for one unit of the good is indicated on your screen: it is the value that you attribute to that unit. Therefore, if your valuation is V and you buy one unit at a price P, your profit will be V – P.

If you do not buy any unit of the good, your profit will be zero. You are not obliged to buy. For example, if the selling price is higher than your valuation, you will not be able to buy the unit of the good. Furthermore, although the software allows you to buy the unit at your valuation, we recommend you to make at least 1 point of profit for each unit that you buy.

Each of the 5 phases that follow consists of 3 trading periods.

Every trading period lasts 2 minutes (120 seconds). In each trading period:

- Each seller can sell several units of the good; each buyer can buy at maximum one unit of the good.
- The production cost is the same for each unit of the good across sellers; the valuation for each good unit can be different for each buyer.
- You can make offers, either to sell or buy, only using integer numbers within 0 and 30.

In each of the 5 phases:

- the unitary production cost for each seller is the same across trading periods;
- the valuation for the same buyer can change across trading periods.

How to exchange: double auction During each trading period, you will have the possibility to submit an ask price (if you are a seller) or a bid (if you are a buyer) according to the same mechanism that we have explained to you during the first tutorial of the course (double auction).

The only difference relative to the first tutorial is that ask prices and bids will be made through a software installed in each of the 28 computers of the laboratory.

Now, we are going to illustrate how to use the software [*sellers and buyers are shown the computer screens reported respectively in Figures A.4 and A.5 of Appendix A*].

If you are a seller: You can submit an ask at any time during the trading period. An ask is entered in the box labeled "Your sell offer" on your screen. The entered ask represents the lowest price that you are willing to accept for a unit of the good.

If you are a buyer: You may submit a bid at any time during the trading period. A bid is entered in the box labeled "Your buy offer" on your screen. The entered bid represents the highest price that you are willing to pay for a unit of the good.

How trades are made: If a seller's entered ask becomes the current lowest ask in the market and it meets or is below the current highest bid, a trade is made between that seller and the buyer holding the current highest bid. Symmetrically, if a buyer's entered bid becomes the current highest bid in the market and it meets or is above the current lowest ask in the market, a trade occurs between that buyer and the seller holding the current lowest ask.

Information shown on your screen: Throughout each trading period, the current highest asks and bids, the number of units already traded (sold/bought) and the number of units still available for sale and for purchase in the market will be shown on all participants' screens (upper part). The bottom part of the screen is your private information. On the right side, it shows the interactive box through which you can submit your asks (if you are a seller) or bids (if you are a buyer). On the left side, it shows your situation in terms of: assigned cost and current lowest ask (if you are a seller), assigned valuation and current highest bid (if you are a buyer), price at which you have traded a unit and profit obtained for that unit.

On the one hand, sellers can sell a given number of units of the good to sell, which varies depending on the phase. On the other hand, each buyer can only buy a maximum of one unit of the good in each period.

Is everything clear? If you have questions, please raise your hand and the experimenter will answer them privately.

[*At the end of the General Instructions, instructions of Phase 1 are shown on each participant's screen.*]

Phase 1 (*Perfect Competition*)

In each of the 3 trading periods:

- Each of the 4 sellers can sell 24 units of the good.
- Each of the 24 buyers can buy at maximum one unit of the good.

[*At the end of Phase 1, instructions of Phase 2 are shown on each participant's screen.*]

Phase 2 (*Perfect Competition with quotas*)
This phase is the same as Phase 1. The only difference is that, in each trading period:

- Each of the 4 sellers can sell at maximum 6 units of the good.

[*At the end of Phase 2, instructions of Phase 3 are shown on each participant's screen.*]

Phase 3 (*Cartel*)
This phase is the same as Phase 1 (each of the 4 sellers can sell at maximum 24 units of the good). The only difference is that, before the start of the phase, the 4 sellers can agree upon the price to apply to all the units to sell in the subsequent trading periods of this phase.

The agreement is implemented through the following rules (keeping anonymity among sellers):

- Each seller writes down on a paper the price that he/she would like to apply to all the units in the following three trading periods of this phase.
- The experimenter collects each price proposal from each seller.
- The experimenter computes the average of the prices that the four sellers have indicated: such average price is the only one that the four sellers should offer in each trading period during this phase.

The experimenter shows to each seller the price proposed by the other three sellers and the average price they should propose.

If they want, sellers can make offers that deviate from such average price. They are not obliged to respect the agreement.

[*At the end of Phase 3, instructions of Phase 4 are shown on each participant's screen.*]

Phase 4 (*Cartel with quotas*)
This phase is the same as Phase 3. The only difference that, in each trading period:

- Each of the 4 sellers can sell at maximum 6 units of the good.

[*At the end of Phase 4, instructions of Phase 5 are shown on each participant's screen.*]

Phase 5 (*Monopoly*)

In each of the 3 trading periods, there are 4 similar markets. The four markets are similar in the sense that, in each of them:

- There are only 1 seller and 6 buyers.
- The seller can sell at maximum 6 units of the good.
- Each of the 6 buyers can buy at maximum one unit of the good.
- The distribution of the valuations of the 6 buyers is the same among markets.