Collusion through Worker Movement: An Experiment

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Abstract

We implement Bertrand price competition in experimental markets with either two or four firms in which firms are comprised of two-subject teams who can discuss pricing decisions. Our experimental design introduces a a coarse channel for inter-firm communication that may facilitate collusion in a novel way: subjects moving between firms in the same market. We find that prices increase significantly after subject movement: 27.5% in markets with two firms and 115% in markets with four firms. The frequency of firms splitting the market at price above the Nash equilibrium, also increases significantly after subject movement, but price coordination remains difficult to achieve and sustain. Team chats indicate that collusion is a frequent topic of discussion before the switch, and more frequent discussion of collusion in a market before subjects change firms is associated with significantly higher prices after subjects have changed firms.

Keywords: collusion, teams, worker movement, experiment
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1 Introduction

"People change jobs out here without changing carpools."

—a Silicon Valley-based engineer quoted in Almeida and Kogut (1999)

Workers routinely change jobs for a variety of reasons. Much of this movement is between firms within the same industry or market where returns to past experiences or industry-specific skills are likely to be higher. Such intra-industry movement has long been recognized as potentially beneficial to the flow of ideas, e.g., diffusion of technologies leading to lower costs (Stoyanov and Zubanov, 2012) or geographic proximity leading to increasing numbers of patents (Atkin et al., 2017), though it may also result in reductions in overall welfare, e.g., regulatory capture via the revolving door (Asai et al., 2021; Katic and Kim, 2024). Our focus is on a heretofore unstudied outcome of worker movement: collusion.

Collusion, defined in Harrington (2017) as "when firms coordinate behavior to suppress competition through activities such as raising prices, allocating markets, and bid rigging," is an elusive target for regulators. Ultimately, only some collusive behavior is uncovered by authorities in real time, but there is a robust literature trying to identify collusion empirically after the fact, (e.g., (Porter, 1983; Abrantes-Metz et al., 2006; Miller, 2009)). This approach to detecting collusion arises because most cases lack the veritable "smoking gun" of direct communications between firms that would constitute *per se* illegal explicit collusion. This may be either because firms are clever enough to communicate without being caught, or that they are engaged in tacit collusion. Tacitly colluding firms do not communicate directly but typically require a mutual understanding or signal of a desire to collude, which is more difficult to prove and may resemble ordinary market behavior. There are obvious reasons that firms might or might not use each. Explicit collusion is likely easier to establish and maintain but raises the specter of criminal and civil penalties, whereas tacit collusion is less likely to result in sanctions, but achieving the requisite "meeting of the minds" is a high bar to clear, and enforcement collusive arrangements is difficult. Workers moving between firms can provide a channel to propagate collusive ideas in a market that is not exactly explicit, nor is it precisely tacit. Workers may discuss collusion with colleagues before moving may have the same discussion with colleagues after moving, but as an employee of the new firm, this is not exactly direct communication between firms. Alternatively, recently arrived workers may care about the well-being of previous colleagues in ways that make them less inclined to compete fiercely with that former colleague, or they might share "best practices" that would enable firms to tacitly harmonize behavior, though there is some information moving from one firm to another.

In order to investigate this, we conducted a laboratory experiment in which "firms" made pricing decisions in each round of an indefinitely repeated Bertrand game. Firms faced computerized demand for up to 200 units of a homogenous good in each round and had no marginal costs; "consumers" purchase at the lowest price in the market. Each firm is composed of two subjects who could chat with one another. After 16 periods, firms learn that one member will move to another firm in the same market at the beginning of period 21, while the current firm would receive a new member from another firm in the market. We employed this set-up in two treatments, one with two firms per market (*2F*) and one with four firms per market (*4F*). We find that prices increase significantly after subjects change firms: by 27.5% in *2F* markets and 115% in *4F* markets. While some of this increase in prices comes from firm successfully splitting the market at high prices, which doubles in frequency in the *2F* markets and begins to occur in *4F* markets, much of it stems from unsuccessful attempted collusion: after workers move, the distribution of firm prices shifts significantly to the right and the modal firm price, which is not necessarily the market price, is the highest price available to the firms. Turning to subject chat records, we find that discussion of collusion increases significantly in periods 17-20, and that discussing collusion in those periods is associated with significantly higher prices after the switch in both *2F* and *4F* markets.

The rest of the paper is organized as follows. Section 2 provides an overview of the related literature. Section 3 details the experimental design. Section 4 lays out our hypotheses, while Section 5 provides the analysis and results. Finally, Section 6 concludes with brief discussion of our results, policy implications, and directions for future research.

2 Literature Review

There is an expansive literature on collusion. Early theoretical models show that repeated interaction can support collusive behavior across various market structures and information environments through, for example, price wars (Green and Porter, 1984) or trigger strategies and dynamic incentives (Abreu (1986), Rotemberg and Saloner (1986)). More recent work has expanded these models to incorporate complex environments, such as those with private monitoring and bounded rationality. For example, Athey and Bagwell (2001) show that firms can achieve tacit collusion even when their signals are noisy and not publicly observable, particularly by favoring higher-cost firms with increased market share in future periods as part of the collusive agreement. Many of the predictions of these theory models have been borne out empirically, e.g., Porter (1983) presents early evidence from the railroad industry, showing that price wars were strategically used to discipline firms and maintain collusion under imperfect monitoring, and Byrne and de Roos (2019) find tacit coordination in the Australian retail gasoline market, especially in environments where firms could easily monitor rivals and entry threats were minimal. Levenstein and Suslow (2006) offer a broad survey of over 150 cartel cases and identify concentration, transparency, barriers to entry, and low demand volatility as critical determinants of cartel stability.

Experimental studies using laboratory markets provide robust evidence on the behavioral and structural mechanisms that sustain collusion. Communication, even when seemingly irrelevant or non-binding, significantly enhances coordination, e.g., Crawford (1998), Potters and Suetens (2013), and coordination as collusion is no different. For instance, Cooper and

Kühn (2014) find that in environments with unrestricted communication, firms use chat to enforce discipline, threats and renegotiation, thereby stabilizing high prices. The format and richness of communication also matters: Brosig et al. (2003) find that open chat enables stronger coordination than numeric messaging, while Dufwenberg and Gneezy (2000) show that greater market concentration facilitates collusive behavior in price competition. The structure of the market also plays a crucial role. Tacit collusion is more readily sustained in duopolies than in larger markets (Isaac and Reynolds, 2002), and a meta-analysis of oligopoly experiments finds that increased firm numbers can disrupt price coordination (Horstmann et al., 2019). Fonseca and Normann (2012) add to both the communication and market structure literatures in experimental Bertrand markets very similar to those we implement. They show that direct communication significantly raises prices, but that the benefits vary by market size. Direct communication allowed greater collusion in markets of all sizes, but duopolies exhibited some collusive behavior even in the absence of communication, limiting the benefits. By contrast, larger markets show no collusion without communication, but collusive arrangements were the least stable in the largest markets. The greatest benefit to collusion occurred in intermediate-sized markets with four firms. Although our markets are similar to Fonseca and Normann (2012), the amount of communication available in our markets is in-between their two treatments and occurs only indirectly through worker movement.

Worker movement between firms has a variety of effects on knowledge and skill transfers (Jaffe et al., 1993; Singh, 2005). For example, Almeida and Kogut (1999) show that, in the context of engineers in Silicon Valley, intra-regional mobility has an outsized impact on dissemination and development of technological expertise. Reinmuth and Rockall (2023) provide causal evidence that inventor mobility increases innovation, particularly in settings with weak non-compete enforcement. Similarly, multinational firms make production location choices with an eye towards the risk that local production, as opposed to importing, risks spreading their technology to local competitors through workers leaving for those firms

(Fosfuri et al., 2001; Glass and Saggi, 2002; Görg and Strobl, 2005). This dilemma has an analog in the related literature on non-compete and non-disclosure agreements, where legal restrictions on labor mobility are meant to discourage information passing between competitors via worker movement. Garmaise (2011) shows that tighter enforcement reduces executive mobility, suggesting that such legal constraints limit the cross-firm transfer of managerial expertise. Samila and Sorenson (2011) find non-compete enforcement dampens entrepreneurship and regional growth, particularly by reducing the positive externalities from venture capital in innovation ecosystems, and Marx et al. (2009) find strengthening non-compete enforcement significantly lowers inventor mobility and innovation rates. In contrast, studies of state-level bans such as Hawaii's prohibition on non-competes in the technology sector and Oregon's restriction for low-wage workers, find that eliminating such agreements increases job mobility and improves labor market outcomes (Balasubramanian et al., 2022; Lipsitz and Starr, 2022). In our setting, the "technology" spreading through worker mobility is collusive pricing. Firms wish to encourage the diffusion in this context rather than limit it.

The paper most closely related to ours is Cooper and Kagel (2018). Subjects in their experiment play a two-person, sequential move game with perfect information in teams of two for 15 rounds. The game has a simple strategy that, when played by the first mover, always results in victory. In one treatment, subjects are re-matched every 5 periods to examine how team switching influences "learning contagion," i.e., the spread of the winning strategy which is not obvious but is easily explained. Team switching substantially increases the fraction of optimal play and matches the demanding truth-wins norm. While subject movement between teams providing a channel to disseminate ideas is very similar across the two studies, the primary — and substantial — difference is the idea spreading through the community of interest. Cooper and Kagel are studying the diffusion of a dominant strategy, analogous to a clearly superior practice or technology spreading in an industry. In our Bertrand games, on the other hand, the idea of colluding with rivals may spread, but it requires coordination, is fragile, and comes with substantial risk.

3 Experimental Design

Our experimental design is similar to that in Fonseca and Normann (2012), which looks at the effect of explicit communication on collusion. We analyze Bertrand oligopoly markets with inelastic demand and constant marginal cost of production for a homogeneous good. In our design, there are $q = 200$ consumers who demand one unit of the good and are willing to pay any price up to $p = 100$. Firms in the market select their prices independently. Prices can be any integer in $[0, 100]$, and buyers purchase from the firm with the lowest price ($p^{\min}$). In the event that more than one firm sets the same lowest price, the firms with the lowest price share the demand evenly. Any firm that does not set the lowest price earns zero profit. This stage game was repeated 40 times, after which the game continued with probability $\frac{5}{6}$, which was common knowledge.[1] Each session had at least two markets, and the number of periods was common to all markets in a session.

Each session consisted of at least 8 subjects, who were given written instructions that were read aloud at the front of the room before subjects completed a comprehension quiz.[2] Firms in *2F* were denoted as Firm Red and Firm Blue, while *4F* markets also had Firm Yellow and Firm Green. Firms consisted of two subjects who could communicate with each other using a chat window. Subjects were aware that they could only communicate with the other person in their firm, and no other firms or subjects could see their messages. Messages were free-form, subject to the standard admonitions that subjects not to identify themselves or post offensive messages. While free-form communication removes some experimental control and poses analytical challenges, it also provides very rich data and is commonly used in experimental economics to facilitate cooperation (Crawford, 1998; Brosig et al., 2003; Dugar and Shahriar, 2018). Before the first period of the Bertrand game, subjects were given 5

[1] Sessions had between 41 and 43 periods. We restrict our analysis to the 40 periods that are common to all sessions, though the results are essentially unchanged using all periods.

[2] The instructions, comprehension questions, and screen shots can be found in the appendix.

minutes to work together using the chat window to answer five incentivized trivia questions.[3] At the beginning of period 17, subjects were informed that one subject would be leaving the current firm for another firm at the beginning of the 21st period.[4]

Before subjects could chat, they could suggest a price they wanted to set; in the first two periods, subjects had 30 seconds to suggest a price, thereafter they had 15 seconds. After suggesting a price, subjects had 3 minutes to chat before periods 1, 2, 21, and 22 (i.e., the first two Bertrand periods with a new teammate), and 60 seconds to chat in all other periods. In *4F*, if there was a disagreement when setting prices, prices were set by the majority rule. In *2F* or a lack of a majority in *4F*, the computer chose one of the prices selected within the firm randomly, with each price being equally likely to be selected.[5]

At the end of each period, a screen displayed the price chosen by all the firms in the market, as well as the firm's stage game and cumulative payoffs. After the completion of all market periods, subjects completed a questionnaire that included demographic questions as well as measures of trust, risk preferences, time preferences, positive and negative reciprocity taken from the Global Preference Survey (Falk et al., 2018), the Ten Item Personality Measure (TIPI) measure of the Big 5 personality traits Gosling et al. (2003) and an incentivized measure of cognitive ability.[6]

The experimental details can be found in Table 1. Subjects received a show-up fee of \$7 plus their cumulative payoffs from the Bertrand markets; and their earnings from the questionnaire. The exchange rate in *2F* was \$1 = 15,000 Experimental Currency Units (ECUs), while the exchange rate in *4F* was \$1 = 5,000 ECUs. The exchange rates differed

[3] Subjects earned \$0.50 for each correct answer.

[4] Introducing a lag between when subjects learn that a teammate will be moving and the actual move is a nod to real workplaces where workers generally give some notice that they are leaving. The collusive dynamic we conjecture is less likely to occur without this lag, but a coworker disappearing overnight without warning is also not how most moves occur.

[5] If none of the subjects within a firm selected a price, a random price between 0 to 100 was selected by the computer. If at least one employee selected a price, that selected price would be the firm's price. There were no cases in which no one in a team entered a price.

[6] All survey questions are provided in the appendix. The cognitive ability measure consisted of the Cognitive Reflection Test (CRT, Frederick (2005)) and three sample Wonderlic questions; subjects were paid \$0.50 for each correctly completed question.

because we anticipated that there would be large differences in market prices between *2F* and *4F*, a conjecture which is clearly borne out in the data, and we wanted the payoffs to be similar across treatments. A total of 320 students participated in 31 sessions conducted at the Behavioral Business Research Lab at the University of Arkansas. Subjects were recruited using the SONA system and the entire experiment was programmed in oTree (Chen et al., 2016).[7] Sessions lasted approximately 90 minutes and the average total earnings were $22.02 in *2F* and $19.68 in *4F*.

4 Hypotheses

We begin by providing a simple theoretical benchmark for game in our experiment. Given that firms can only set integer prices in $[0, 100]$ and can sell at most 200 units, the Nash equilibrium of the stage game in a market with N firms is for all firms to set a price of 1, earning a profit of

$$\pi^{NE} = \frac{p^{\min} \cdot q}{N} = \frac{200}{N}.$$

If $n \leq N$ firms collude at a price $p^{coll} > 1$, their stage game profit is

$$\pi^{coll} = \frac{200 p^{coll}}{n},$$

Assuming that firms discount the future with discount factor δ, we can denote the present value of collusion as

$$V_C = \sum_{t=0}^{\infty} \delta^t \pi^{coll} = \frac{\pi^{coll}}{1-\delta}$$

A firm that defects earns a stage game payoff of $\pi^D = 200(p^{coll} - 1)$ in the period in which they defect. If we also assume that defection leads to the Nash outcome thereafter

[7] We intended to collect data for 24 markets in both *2F* and *4F*, but the first 8 *2F* did not include the ice-breaker due to a technical issue. Excluding those markets does not change our results.

(i.e., a grim trigger strategy), then the present value of defecting in the current period as

$$V_D = \pi^D + \sum_{t=1}^{\infty} \delta^t \pi^{NE} = \pi^D + \frac{\delta}{1-\delta}\pi^{NE}$$

Firms can sustain collusion if $V_C > V_D$, or

$$\delta > \frac{\pi^D - \pi^{coll}}{\pi^D - \pi^{NE}}$$

Given the parameters of our experiment, this means that firms can sustain collusion at p^{coll} if

$$\delta \geq \frac{np^{coll} - n - p^{coll}}{np^{coll} - n - 1} \tag{1}$$

The discount factor necessary to support collusion is increasing in p^{coll} and n.[8] With this in hand, we have the following hypothesis:

Hypothesis 1. *Market prices are higher and collusion more frequent in 2F markets than in 4F markets*

Given (1), δ is lower for a given price when n is lower, so we expect *2F* markets to meet this criterion more frequently. This should lead to at least weakly higher prices on average.

Beyond the predictions of this simple model, we have several behavioral conjectures surrounding collusion. First,

Hypothesis 2. *After the switch, collusion is more common and prices are higher than before the switch.*

As noted earlier, communication facilitates collusion, so we expect the coarse communication channel afforded by employee movement to also facilitate collusion making it easier to establish. This should lead to at least weakly higher prices on average.

Hypothesis 3. *The relative gains to firms of collusion will be greater in 4F markets than in 2F markets.*

[8] The derivation is in Appendix B.

Fonseca and Normann (2012) found that two-firm markets managed to collude occasionally in their very similar experiment even in the absence of communication, so the scope for increased collusion was more limited with two firms than in markets with more firms where collusion almost never occurred without communication.

We also make two conjectures about the mechanisms driving the increased collusion resulting from subjects moving between firms. First, a subject may be less willing to profit at the expense of a previous partner due to diminished social distance, which leads to less competitive pricing decisions. Bonhomie of this sort is closely related to the value of having former government employees as outside directors. For example, Lester et al. (2008) find that greater "social capital" increased the likelihood that former government employees were brought on as outside directors, i.e., government workers with closer relationships with their government coworkers are more valuable to firms as outside directors. The rationale is that outside directors' good relationships with past colleagues lead to more favorable regulatory outcomes.

Hypothesis 4. *Price increases after the switch are due to diminished social distance between competing firms.*

Second, collusion between firms may occur because incoming workers bring messages of a willingness to collude from a previous firm. Subjects are aware that this movement may occur from the beginning of the experiment, but we also anticipate that firms who wish to send collusive messages with an outgoing worker are more likely to discuss collusion in periods 17-20 when they know for sure who will be moving.

Hypothesis 5. *Prices increase because moving subjects bring with them messages of willingness to collude.*

5 Results

5.1 Prices

Result 1. *Prices are significantly higher after the switch than before for both 2F and 4F markets. Prices are significantly higher in 2F markets than 4F overall, before the switch, and after the switch. There is more collusion in 2F markets than 4F overall, before the switch, and after the switch. H1 and H2 are strongly supported.*

Result 2. *The percentage increase in prices in 4F markets is roughly four times that in 2F markets, while the percentage increase in the frequency of collusion is 23 times higher in 4F markets than 2F markets. H3 is strongly supported.*

Figure 1 plots the average prices by period and the number of firms. It is readily apparent that the prices in the *2F* markets are substantially above those in the *4F* markets, as the average in *2F* markets is at least twice that in *4F* markets in essentially every period. Table 2 summarizes the average prices for all periods, those before the switch, and those after the switch. The average overall price in the guaranteed periods is higher in the *2F* markets than in the *4F* markets: 36.4 vs. 10.6 (rank-sum $p < 0.001$).[9] This price ranking is the same throughout: *2F* markets have significantly higher prices than the *4F* markets before the switch (32.0 vs. 6.7, rank-sum $p < 0.001$) and after the switch (40.8 vs. 14.4, rank-sum $p < 0.001$).[10] These comparisons, as well as the visual evidence in Figure 1, also demonstrate a clear increase in prices within treatments from before the switch to after. Using all guaranteed periods, prices increase 27.5% in *2F* markets, from 32.0 to 40.8 (signed-rank $p = 0.043$). In *4F*, the percentage increase in prices is even starker: the average price

[9] The unit of observation for the statistical tests in this section is average price in a market over all periods in the time frame under consideration, i.e., overall, before the switch, or after the switch. This means that in any time frame under consideration, there are 32 observations for the *2F* markets and 24 observations for the *4F* markets. We also use only the 40 guaranteed periods, though the results are similar using periods after the 40^{th}.

[10] As a point of reference, our *2F* markets have slightly lower prices than in Fonseca and Normann in the absence of communication (32.0 vs. 50.4), while our *4F* markets have slightly higher prices (6.7 vs. 6.0), but the direct communication in Fonseca and Norman is dramatically better at generating collusion than subject movement in both *2F* (40.8 vs. 93.5) and *4F* (14.4 vs. 81.3) markets.

increases by 115%, from 6.7 to 14.4 (signed-rank $p = 0.009$), from before the switch to after.

To determine whether a market exhibits "collusion", we define a market-period to be collusive if at least two firms in the market sell at a price above 1. This means both firms in *2F* set the same price above 1 and at least two firms in *4F* set the same price above 1. As can be seen in the top panel of Table 2, collusion of this sort is substantially more common in the *2F* markets. Overall, 12.7% of market-periods are collusive in *2F*, whereas 7.2% are collusive in *4F* markets. In *2F* markets, the percentage of collusive market-periods increases 94.2% after the switch from 8.6% to 16.7%. In *4F* markets, the fraction of collusive market-periods increases 88% from 5.0% to to 9.4% (χ^2 $p < 0.001$) and the average price increases 308% from 11.4 to 46.5 ($p = 0.086$).

Table 2 breaks out the average selling prices before and after the switch in markets that are or are not collusive. In *2F*, non-collusive market-periods have an average selling price of 30.2 before the switch and 33.5 after the switch ($p = 0.220$), while collusive market-periods see a 50% price increase from 51.4 before the switch to 77.3 after ($p < 0.001$). In *4F* markets, non-collusive prices increase from 6.5 to 11.1 ($p = 0.004$), and collusive prices increase from 11.4 to 46.5 ($p = 0.086$).[11]

Measuring collusion this way is instructive but does not capture the whole story. Even the 95% of *4F* market-periods that are not collusive by our definition have significantly higher prices after the switch, with prices rising 58%. Although they may not be successful, subjects are trying to collude, and post-switch prices reflect *attempted* collusion. Figure 2 is a histogram of prices set by individual firms in *2F* (top panel) and *4F* (bottom panel) regardless of whether or not it ends up being the market price. Prior to the switch, firm prices in the *2F* markets are already generally above 1, and no single price accounts for even 5% of the firm-period observations. On the contrary, *4F* prices are distinctly bimodal:

[11] Using a more stricter definition for *4F* markets, where we require at least three firms to set the same price above 1, only one market-period is collusive prior to the switch (0.2%), and 4.8% market-periods are collusive after switch (χ^2 $p < 0.001$). Collusive market-periods under this definition have an average selling price of 83.0, and the only collusive market-period before the switch had a price of 5.The p-values for prices come from a regression of market-period prices on a dummy equal to one if the observation comes from after the switch. Standard errors are clustered at the market level.

28.2% of prices are equal to 1 and 12.2% of prices are 100.[12] After the switch, the modal price in both treatments is 100: 11.3% of prices in *2F* and 22.1% of prices in *4F*.

While attempting to collude at 100 is common, establishing collusion at any specific prices proves particularly difficult because the chat records discussed below reveal that subjects often discuss colluding at "high" prices but do not choose a specific price. After the switch, one firm arbitrarily sets a high price, e.g., 95, at which they hope to collude. The other firm sets a different price, e.g., 90 or 100, also attempting to collude, and they fail to coordinate. This leads to cycles of firms attempting to coordinate, which can be seen in the evolution of market prices in each market in Figure 3. Further illustrating the desire for but inability to establish collusion, Figure 4 shows kernel density plots of interior prices, i.e., those between 1 and 100, before and after the switch in the *2F* (top panel) and *4F* (bottom panel) treatments. There is a clear shift toward higher prices in both markets, and the distribution of these interior prices after the switch is significantly different from that before (Epps-Singleton $p < 0.001$ for both).

5.2 Chat classification

We analyze subject chat records to better understand subject motivations. To do so, we first read through all of the chats and established a set of categories that cover the most common topics that subjects discuss. This exercise resulted in three broad categories, each with several subcategories: General Discussion, Non-collusive Price Setting, and Collusion; the exact codes can be found in Table 3. We utilize OpenAI's GPT-4 language model to classify chats at the firm-period level by submitting each firm-period chat to the GPT-4 model using OpenAI's API, which allows users to send prompts and receive model-generated

[12] Subjects can choose to set a price of 0. Although this is strictly dominated, it does occur in both treatments. Out of 1,280 prices before (after) the switch in *2F*, three (two) are 0. In *4F*, 2.2% of prices are 0 before the switch and 3.1% of prices after the switch are 0. The chats reveal that the motivation behind choosing 0 is primarily trying to express annoyance with a rival firm that refuses to move off a price of 1, or (in conjunction with previous or subsequent prices) as part of collusive communication to either suggest collusion or punish deviation. For example, a player in the Red firm in period 11 of one *4F* market says, "Should we just start doing 0 so blue stops doing that" after the Blue firm continues to undercut everyone at a price of 1, to which his teammate responds, "keep it up until the lowest goes up".

responses through a simple automated interface using a standardized prompt.[13] The prompt included: (i) a brief description of the market context (*2F* or *4F*), (ii) the instructions participants received, and (iii) the full list of categories. We instructed the model to read the chat logs and return only the applicable codes in a comma-separated list (e.g., 2.f, 3.g). If the model could not classify a chat, it returned "None."[14] Each firm-period was processed independently, using the same static prompt across all sessions. The model was not provided with outcome data or price information, and no fine-tuning or feedback was applied during classification. This ensured consistent labeling, with each chat classified independently of prior communication history.

5.3 Chat results

Result 3. *There is no evidence that concern for the payoffs of a previous partner enter into pricing decisions. H4 is not supported.*

While we conjectured that diminished social distance might influence pricing after the switch, there are *no* messages that convey this sentiment. Although there are some fond goodbyes, no one ever discusses the welfare of a previous partner as motivation for collusive prices, though some express surprise that a former partner plays aggressively or undercuts them.[15] As such, we did not include a code for this.

[13]The model we used was quickly superseded; categorizations and our subsequent results do not change if we use GPT-5 model instead.

[14]The full text of the prompt can be found in the appendix. There were 5,636 total firm-period chats: 2,530 in *2F* and 3,106 in *4F*, of which 116 (389) were uncategorized in *2F* (*4F*). Uncategorized chats are mostly too short to be assigned to a category: only 51 had more than 20 characters, with an average length of 8.9 characters compared to 92.4 for categorized chats. The median length of an uncategorized chat in *2F* (*4F*) is 8 (5) characters. These tend to be an exchange of messages like "6?", "k", and "bet."

[15]An example of this sort of thing is:
Player Red 1: is this our last period togehter <\3
Player Red 2: i thinkk
Player Red 1: sad
Player Red 2: it has been real :(don't forget me lmao
Player Red 1: i will never forget u player red 2
In the next period, Red 1's team chooses 3 and Red 2's team chooses 19.
Player Red 2: 3?????????? BOO!!!!!!!!!!
Later in this conversation, Red 2 explains to his new partner, "im just shocked they did 3."

Table 4 provides the full list of chat code assignments. Unsurprisingly, the most commonly coded categories in both treatments are generic discussions of price setting, 2.f and 2.g. These account for 55.7% (37.7%) of all chats in *2F* (*4F*). The third most common coding in both treatments, however, was 3.c, "Set a high price to signal collusive intent." Overall, messages included in our collusion category account for 14.8% (20.5%) of all messages in *2F* (*4F*). If subject movement does allow a channel for collusive messages, then we should not expect collusive messages to be uniformly distributed across all periods. Given our treatment, collusion should be a more common topic of conversation in periods 17-20 — when a subject knows they will switch teams but before they have done so — than in the first 16 periods because the soon-to-move subject can carry this message to the new firm. After the switch, moved employees trying to implement collusive outcomes would share these messages with the new firm, so we should also expect to see more chat in the periods immediately after the switch. This is exactly the pattern that emerges. The proportion of all messages that are collusive in *2F* increases from 12.5% in the first 16 periods to 17.5% ($p = 0.023$) in periods 17-20, while the proportion after the switch (17.4%) is also significantly higher than in the first 16 periods ($p < 0.001$). In Figure 5, which plots the total number of firm-period messages in the Collusion category over the periods of the experiment by treatment, the two periods with the most collusive messages in *2F* are periods 21 and 22. The evidence is even more striking in *4F*, where the proportion of collusive messages increases from 18.3% in the first 16 periods to 28.7% in periods 17-20 ($p < 0.001$), and remains elevated after the switch at 21.8% ($p = 0.012$ relative to periods 1-16). Figure 5 shows spikes in collusive message counts in periods 17 (when subjects find out who will move) and 21 (subjects' first period in a new firm); the next two highest message counts were in periods 22 and 23.

The patterns of collusive messages are consistent with our expectations, but does that translate into higher market prices?

Result 4. *Discussing collusion when a subject is about to switch firms is associated with significantly higher prices after the subject switches. Hypothesis 5 is supported.*

In Table 5, we look at the effects of chat *prior* to the switch on market prices *after* the switch. We regress market prices after the switch on several controls from before the switch. The dependent variables in columns 1 and 3 are the average market price for a market in periods 21-40, while the dependent variables in columns 2 and 4 are each individual market-period price from periods 21-40. In our controls, we include the average market price for a market in periods 1-20 to account for the fact that markets with high first-half prices may also have higher second-half market prices due to anchoring or habit. Aside from the first-half average prices, we also include firm-period chat counts for a market in each of our three broad categories (General Discussion, Non-collusive price setting, and Collusion) for two regimes: before subjects find out who will switch (periods 1-16) and after they find out but before they switch (periods 17-20).[16] We find that higher first half prices are associated with higher second half prices in both *2F* and *4F* markets, though it is only (marginally) statistically significant in the former. In *2F*, but not *4F*, the number of general price discussion messages sent in a market significantly impacts second half prices, though in opposite ways for the first 16 periods and periods 17-20. Consistent with our conjecture, the number of collusive messages exchanged between periods 17-20 is associated with significant increases in second-half prices in columns 2-4 (in column 1, $p = 0.13$). The marginal effect suggests that each additional collusive message sent increases prices by 2-3 ECUs, a price increase equivalent to approximately 10% of the non-collusive average price before the switch in 2F markets, and nearly 50% in *4F* markets.

6 Conclusion

Using experimental Bertrand games with firms comprised of two subjects each, we find that subjects moving between firms can facilitate collusion. Prices increased significantly after worker movement, as did the frequency of markets being split by firms charging price

[16]Our results in columns 2 and 4 are robust to the inclusion of a linear time trend or period dummies. These results can be found in appendix table A.1.

above the Nash equilibrium. The gains to firms were relatively greater in markets with four firms than with two firms, largely because the latter were less competitive even before the movement. Using chat records, we see that collusion is a frequent topic of conversation, and that discussing collusion in the critical periods right before moving is associated with higher market prices after the move.

Our results provide three insights for anti-trust authorities attempting to root out collusion. Specifically, in markets where conditions might already be conducive to collusion, e.g., highly concentrated, high barriers to entry, etc., frequent intra-industry movement of workers may serve as the canary in the coal mine indicating that greater scrutiny is warranted. Moreover, firms in similarly at-risk industries that require specific skills not used elsewhere might reasonably be expected to try to prevent competitors poaching from a limited pool of workers by using non-compete agreements. A lack of such agreements may also be indicative that the industry prefers to routinely trade workers to promote collusion. Finally, another dimension of this intra-industry interest in trading workers to encourage corruption is its effect on how human capital formation occurs. One might expect that, in industries colluding in this way, firms would be willing to bear relatively more of the costs of industry specific human capital than in a competitive market. Although these skills could be used at direct competitors, such skills might also increase the likelihood of trading workers within the industry or market to promote collusion. Moreover, firms might be less willing to promote internally than in a competitive market in order to encourage "cross pollination."

There are also several other questions that we cannot answer with our experiment. We conjectured that preferences over the well-being of a former colleague would lead to less competitive pricing but found no evidence of this. Our stylized environment may limit social considerations that may occur in field settings, so the fact that we did not observe them does not mean that they are not real. We have effectively provided one message between firms, but it seems likely that both the number of collusive periods and the prices at which collusion occur would likely both be higher if workers moved frequently. The movement in our experiment is also synchronous, which could affect how likely firms are to try colluding or their ability to establish a specific price. Field evidence of the sort worker movement we are suggesting would be useful, and there is related evidence in a handful of papers about greater collusion between firms that partially share leadership or ownership (e.g., Herrera-Caicedo et al. (2025), Villamil et al. (2024)). Ultimately, observational data that maybe hard to come by for all the same reasons that collusion can be difficult to prove, may be necessary to answer many of these questions, as well as test the implications for anti-trust authorities. We leave these ideas for future research.

Tables and Figures

Table 1: Experimental Details

	Two firm	Four firm	Total
Number of markets	32	24	56
Number of subjects	128	192	320
Average earnings	\$22.02	\$19.68	\$20.62
Exchange rate	\$1 = 15,000 ECUs	\$1 = 5,000 ECUs	

Note: Table reports the number of markets, subjects, and average earnings in each treatment. The exchange rates were calibrated to ensure final earnings were similar regardless of treatment.

Table 2: Average Market Prices

	Two firms			*Four firms*		
	All periods	Before switch	After switch	All periods	Before switch	After switch
Overall	36.4	32.0	40.8	10.6	6.7	14.4
	(26.3)	(21.1)	(29.9)	(19.5)	(12.1)	(24.2)
	$N = 1,280$	$N = 640$	$N = 640$	$N = 960$	$N = 480$	$N = 480$
Non-collusive	31.8	30.2	33.5	8.7	6.7	11.1
	(21.3)	(18.9)	(23.6)	(15.1)	(12.0)	(17.5)
	$N = 1,118$	$N = 585$	$N = 533$	$N = 891$	$N = 456$	$N = 435$
Collusive	68.6	51.4	77.3	34.3	11.4	46.5
	(33.6)	(31.0)	(31.5)	(42.0)	(13.3)	(46.8)
	$N = 162$	$N = 55$	$N = 107$	$N = 69$	$N = 24$	$N = 45$

Note: Prices are in Experimental Currency Units (ECUs). A market is "Collusive" if at least two firms in four-firm markets (and both firms in two-firms markets) set the same price strictly greater than 1. Standard deviations are in parentheses; N is the number of market-period observations.

Table 3: Chat Categories

	General Discussion
1.a	Discussion unrelated to the experiment
1.b	Ran out of time\made a mistake
1.c	Discussing experimental procedures or experimenters
1.d	Disagreement\frustration with own teammate
1.e	Discussing current profit or complaining about losing or not making money
1.f	Frustration with other team
	Non-collusive Price Setting
2.a	Set a low price because it is safemake at least some profit
2.b	Desire to win regardless of profit
2.c	Undercutting competitors
2.d	Set a low price out of anger\spite\punishment
2.e	Avoiding a race to the bottom
2.f	Suggesting or discussing price for their firm\agreeing with teammate abut price or strategy
2.g	Discussing\guessing at trends or the prices of other firms
2.h	Belief about how a former partner will set prices
	Collusion
3.a	Discussion of colluding by taking turns
3.b	Desire to work\communicate with rivals
3.c	Set a high price to signal collusive intent
3.d	Alternating between low and high prices
3.e	Specifically setting a very low price to get the other firms to think about the payoffs
3.f	Discussion of low profits at low prices even as a monopolist\Discussing payout to share the market at a higher price
3.g	Tell your next team to do X\my last partner and I discussed doing X
3.h	Telling new firm to set a higher price than they previously were to increase profits\desire to spread message about the benefits of collusion
3.i	Discussing deliberations/decisions done in previous firm

Note: Table lists the chat coding categories and sub-categories used to classify chats between "employees" within a firm.

Table 4: Frequency of Chat Categories

General Discussion

	Two firms				*Four firms*			
	All Per.	**Per. 1-16**	**Per. 17-20**	**Per. 21-40**	**All Per.**	**Per. 1-16**	**Per. 17-20**	**Per. 21-40**
1.a	48	14	9	22	51	16	4	27
1.b	31	15	2	12	25	7	1	16
1.c	24	10	6	4	27	10	4	13
1.d	18	5	5	6	22	7	2	13
1.e	45	20	9	10	54	22	6	24
1.f	32	12	3	14	52	14	7	29
	13.9%	13.7%	18.5%	11.0%	25.0%	22.4%	26.1%	26.1%

Non-collusive Price Setting

	Two firms				*Four firms*			
	All Per.	**Per. 1-16**	**Per. 17-20**	**Per. 21-40**	**All Per.**	**Per. 1-16**	**Per. 17-20**	**Per. 21-40**
2.a	74	28	13	24	56	28	2	26
2.b	14	5	2	6	18	7	1	10
2.c	70	33	7	28	29	12	2	15
2.d	22	7	0	13	29	9	0	19
2.e	27	13	2	11	16	10	0	6
2.f	537	217	66	231	212	78	20	107
2.g	259	107	30	116	137	54	11	69
2.h	6	1	2	3	2	1	0	1
	71.0%	74.3%	66.3%	69.8%	54.1%	58.7%	39.1%	54.1%

Collusion

	Two firms				*Four firms*			
	All Per.	**Per. 1-16**	**Per. 17-20**	**Per. 21-40**	**All Per.**	**Per. 1-16**	**Per. 17-20**	**Per. 21-40**
3.a	14	2	3	9	10	4	1	5
3.b	11	1	3	7	8	1	2	5
3.c	104	42	9	52	82	30	11	39
3.d	5	0	1	4	4	1	0	3
3.e	5	1	0	4	11	4	2	5
3.f	39	16	5	18	35	14	2	19
3.g	4	0	0	4	10	3	5	1
3.h	16	4	4	8	25	6	8	10
3.i	16	0	3	13	8	1	1	6
	15.1%	11.9%	15.2%	19.2%	20.9%	18.9%	34.8%	19.9%

Note: Counts of firm-period chats by category and sub-category. "Per. 1–16" are pre-announcement periods; "Per. 17–20" are post-announcement & pre-switch; "Per. 21–40" are post-switch. Percentages are relative shares within treatment and broad category group.

Table 5: Post-switch Market Prices and Pre-Switch Chat

	2F		*4F*	
	(1)	(2)	(3)	(4)
First Half Average Price	0.568*	0.583*	1.385	1.153
	(0.282)	(0.308)	(0.970)	(0.754)
Category 1_{P1-P16}	-0.989	-1.187	0.295	0.232
	(0.872)	(0.844)	(0.651)	(0.383)
Category $1_{P17-P20}$	-0.962	-0.685	-1.213	-1.448
	(1.924)	(1.233)	(1.530)	(1.064)
Category 2_{P1-P16}	1.926***	1.958***	0.471	0.511
	(0.541)	(0.308)	(0.629)	(0.347)
Category $2_{P17-P20}$	-3.956***	-3.932***	-0.981	-0.886
	(1.169)	(0.584)	(1.414)	(0.760)
Category 3_{P1-P16}	1.669*	1.682*	-0.510	-0.310
	(0.939)	(0.876)	(1.167)	(0.855)
Category $3_{P17-P20}$	2.224	2.635*	2.287*	2.376*
	(1.420)	(1.408)	(1.276)	(1.201)
Constant	-7.523	-8.457	-11.690	-13.050
	(13.696)	(10.939)	(16.355)	(7.814)
N	32	640	24	480
R^2	0.772	0.628	0.429	0.223

Note: The dependent variables in columns 1 and 3 are the market average price for periods 21-40, while the dependent variables in columns 2 and 4 are the market-period prices for periods 21-40. Standard errors in columns 2 and 4 are clustered at the market level. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

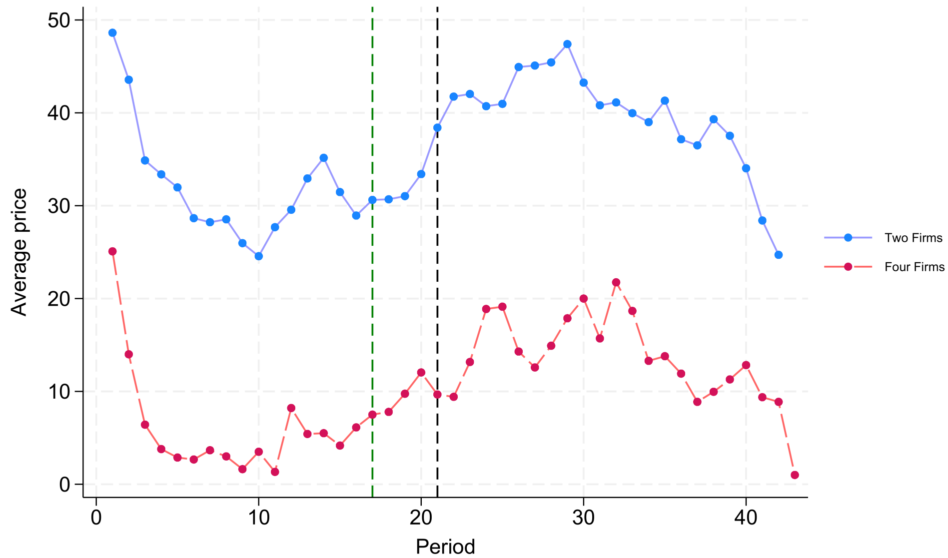


Figure 1: Average Market Prices

Note: Figure plots average winning market prices by period for two-firm and four-firm markets. Vertical dashed lines mark the announcement of worker switch (Period 17) and the first period after switch (Period 21).

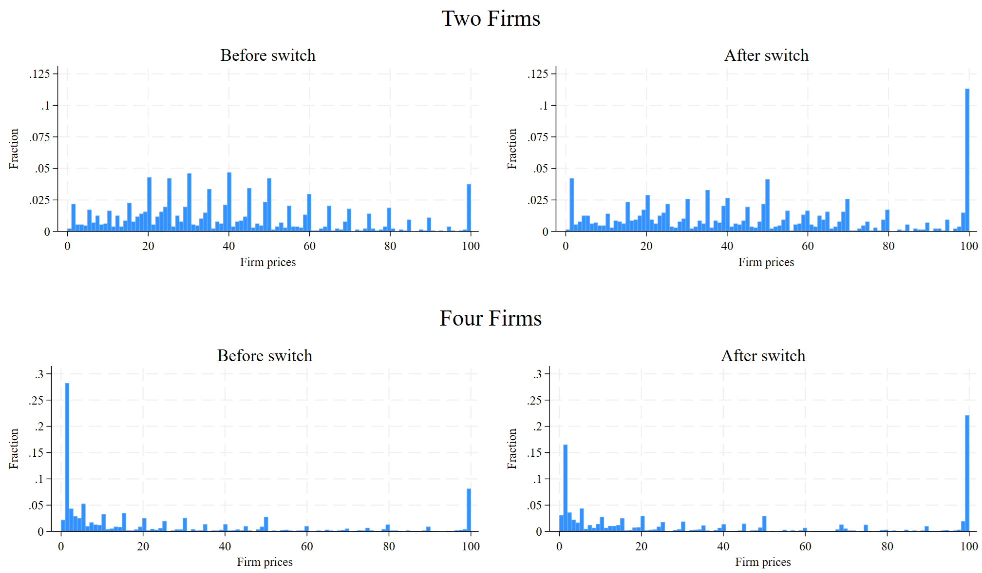
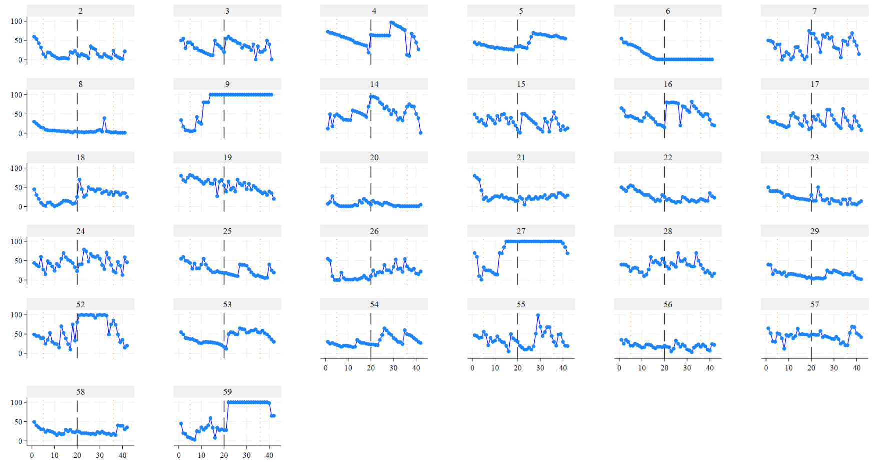


Figure 2: All Firm Prices

Note: Histogram of individual firm prices by treatment. Prices are in Experimental Currency Units (ECUs). Bars show the frequency of all firm-period observations across periods.

(a) Two Firm Markets



(b) Four Firm Markets

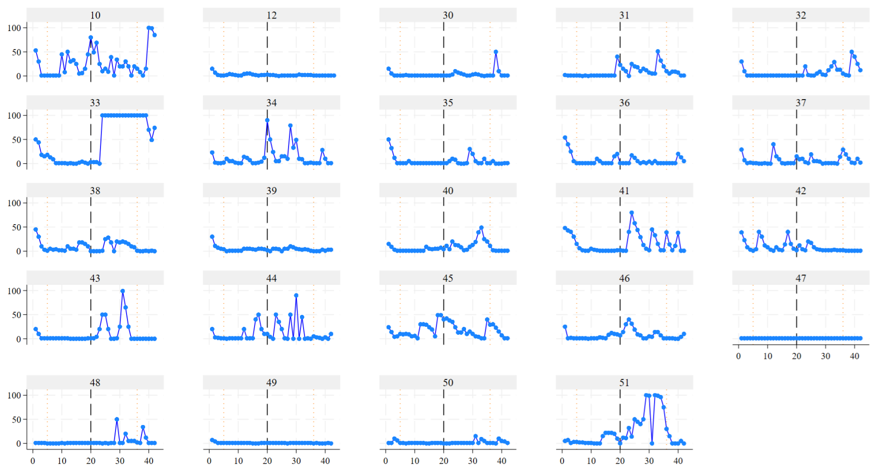


Figure 3: Evolution of Prices in All Markets

Note: Each figure traces one market over the 40 guaranteed periods, separately for two-firm (top) and four-firm (bottom) treatments.

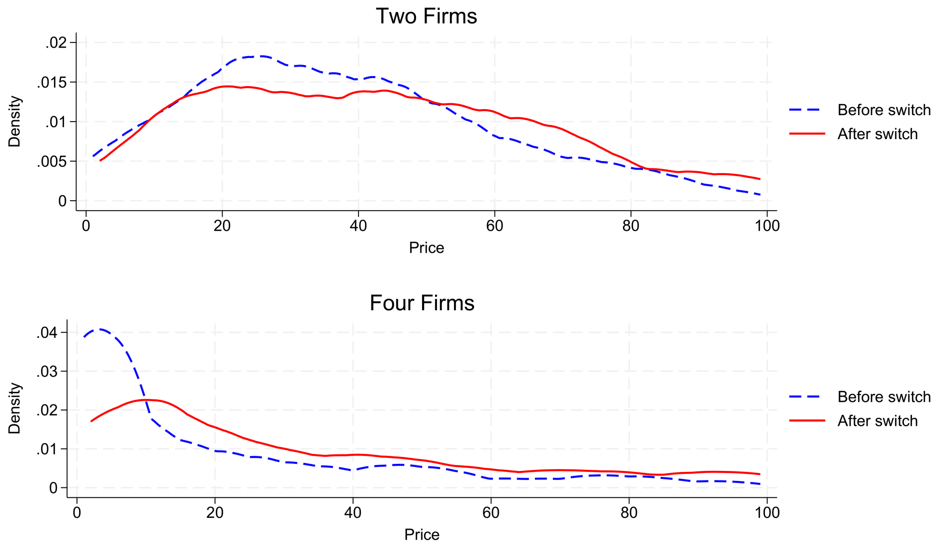


Figure 4: Density of Interior Prices

Note: Kernel density estimates of firm prices strictly between 1 and 100 ECUs, shown before (Periods 1–20) and after (Periods 21–40) the worker switch, separately by treatment.

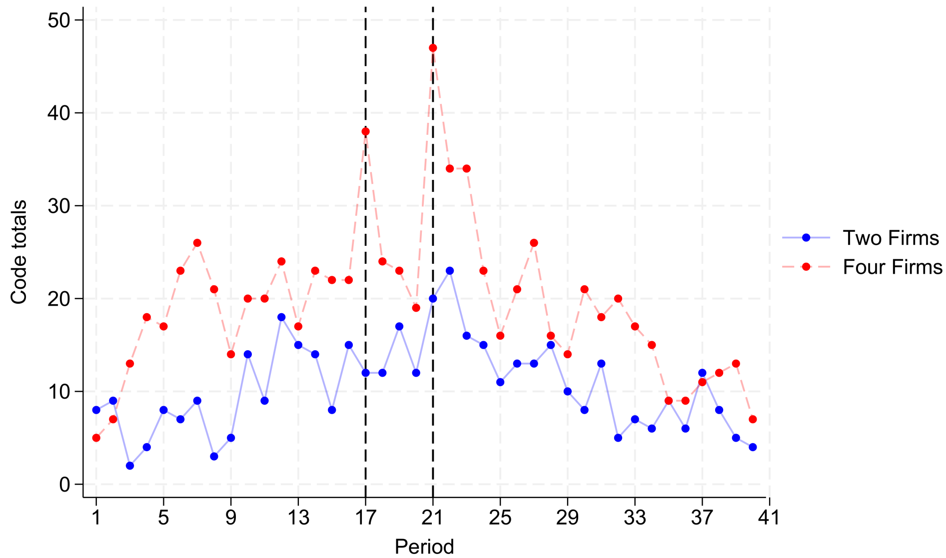


Figure 5: General Collusion chats (Category 3) by period

Note: Total number of firm-period chats classified as Category 3 (General Collusion) by period, plotted separately for two-firm and four-firm treatments. Vertical dashed lines indicate worker switch announcement (Period 17) and first period after the worker switch (Period 21) .

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Appendix

Appendix A: Tables

Table A.1. Post-switch Market Prices and Pre-Switch Chat

	2F		*4F*	
	(1)	(2)	(3)	(4)
First Half Average Price	0.583*	0.583*	1.153	1.153
	(0.308)	(0.313)	(0.755)	(0.770)
Category 1_{P1-16}	-1.187	-1.187	0.232	0.232
	(0.845)	(0.857)	(0.384)	(0.391)
Category 2_{P1-16}	1.958***	1.958***	0.511	0.511
	(0.308)	(0.313)	(0.347)	(0.354)
Category 3_{P1-16}	1.682*	1.682*	-0.310	-0.310
	(0.877)	(0.889)	(0.856)	(0.872)
Category 1_{P17-20}	-0.685	-0.685	-1.448	-1.448
	(1.234)	(1.252)	(1.065)	(1.086)
Category 2_{P17-20}	-3.932***	-3.932***	-0.886	-0.886
	(0.584)	(0.593)	(0.761)	(0.776)
Category 3_{P17-20}	2.635*	2.635*	2.376*	2.376*
	(1.409)	(1.429)	(1.203)	(1.226)
Constant	1.090	-10.888	-9.866	-17.783
	(12.421)	(10.234)	(11.771)	(10.833)
N	640	640	480	480
R^2	0.631	0.640	0.224	0.247
Linear time trend (t)	✓		✓	
Period fixed effects		✓		✓

Note: The dependent variables in columns 1 and 3 are the market average price for periods 21–40; while the dependent variables in columns 2 and 4 are market-period prices for periods 21–40. Coefficients are reported with standard errors in parentheses. Standard errors in columns 2 and 4 are clustered at the market level. This table presents robustness specifications with time controls: columns (1) and (3) include a *post-switch linear time trend* (periods 21–40), and columns (2) and (4) include *period fixed effects* for periods 22–40. Significance levels: $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Appendix B: Derivation of Collusion Incentive Constraint

We provide a simple theoretical benchmark to guide comparative static predictions. Given that firms can only set integer prices, the Nash equilibrium of the stage game in a market with n firms is for all firms to set a price of 1, earning each firm a profit of:

$$\pi^{NE} = \frac{p^{\min} \cdot q}{n} = \frac{200}{n}.$$

If all n firms collude at a price $p > 1$, each firm's stage-game profit is:

$$\pi^{coll} = \frac{200p}{n}.$$

Assuming that firms discount future payoffs using a discount factor δ, the present value of collusion is:

$$V_C = \sum_{t=0}^{\infty} \delta^t \pi^{coll} = \frac{\pi^{coll}}{1-\delta}.$$

A firm that defects unilaterally in a single period earns:

$$\pi^D = 200(p-1),$$

after which all firms revert to the Nash equilibrium forever (grim trigger). The present value of defection is thus:

$$V_D = \pi^D + \sum_{t=1}^{\infty} \delta^t \pi^{NE} = \pi^D + \frac{\delta}{1-\delta}\pi^{NE}.$$

Collusion is sustainable if $V_C > V_D$, which simplifies to:

$$\delta > \frac{\pi^D - \pi^{coll}}{\pi^D - \pi^{NE}}.$$

Substituting in for π^D, π^{coll}, and π^{NE}:

$$\delta > \frac{200(p-1) - \frac{200p}{n}}{200(p-1) - \frac{200}{n}}.$$

Multiplying numerator and denominator by n to eliminate fractions:

$$\delta > \frac{200n(p-1) - 200p}{200n(p-1) - 200}.$$

Simplifying yields the final condition:

$$\delta \geq \frac{np - n - p}{np - n - 1}.$$

This condition implies that the minimum discount factor required to sustain collusion increases in both the collusive price p and the number of firms n.

To verify the comparative statics, let the critical discount factor be denoted by

$$\delta^* = \frac{np - n - p}{np - n - 1}.$$

Taking partial derivatives yields:

$$\frac{\partial \delta^*}{\partial p} = \frac{n(n-1)}{(np - n - 1)^2} > 0 \quad \text{for } n \geq 2 \text{ and } p > 1,$$

and

$$\frac{\partial \delta^*}{\partial n} = \frac{p(p-1)}{(np - n - 1)^2} > 0 \quad \text{for } p > 1.$$

Both derivatives are strictly positive for all $p > 1$ and $n \geq 2$, confirming that the minimum discount factor required to sustain collusion increases in both the collusive price p and the number of firms n.

Appendix C: Instructions, Survey & GPT-4 Prompts

Instructions - 2 Firms

This is an experiment in the economics of market decision making. The instructions are simple, and if you follow them carefully and make good decisions you may earn a **CONSIDERABLE AMOUNT OF MONEY** which will be **PAID TO YOU IN CASH** at the end of the experiment.

Markets

In this experiment, you will act as part of a firm, which is in a market with another firm. The firms produce some good and there are no costs of producing this good. This market is made up of 200 identical consumers, each of whom wants to purchase one unit of the good at the lowest price. The consumers will pay as much as 100 Experimental Currency Units (ECUs) for a unit of the good. This means that your firm can choose any price from 0 to 100, including 0 and 100.

In each market there will be two firms. You will be assigned the role of either Firm Red or Firm Blue. Each firm will be able to supply to 200 consumers. The market will operate as follows. In the beginning of each period, all firms will set their selling prices. If only one firm sets the lowest price, then the firm who set the lowest price will sell its capacity at the selected price, and the other firm will not sell to any consumers. If both firms set the lowest price, then they will split the available consumers evenly. At the end of each period, all the firms are informed of their own price as well as the prices of all firms in the market.

In order to fix ideas, consider the following examples:

Example 1

Suppose that the two firms choose the following prices: Firm Red sets a price of 75 ECUs and firm Blue sets a price of 85 ECUs. Firm Red set the lowest price and sells to all 200 consumers at a price of 75 ECUs, making a profit of 15,000 ECUs. Firm Blue will not sell to any consumers and makes 0 ECUs.

Example 2

Suppose that the two firms choose the following prices: Firm Red and firm Blue both set a price of 70 ECUs. Given that firms Red and Blue set the same price, they will share the available consumers equally. Hence, both firms will sell 100 units at a price of 70 ECUs each unit, making profits of 7,000 ECUs each.

Example 3

Suppose that the two firms choose the following prices: Firm Red sets a price of 90 ECUs and firm Blue sets a price of 3 ECUs. Firm Blue set the lowest price and sells to all 200 consumers at a price of 3 ECUs, making a profit of 600 ECUs. Firm Red will not sell to any consumers and makes 0 ECUs.

Firms

In every period, you will be paired with another subject, and the two of you will act as a firm. You will each be assigned a unique ID, and you will be able to discuss pricing strategy with your teammate using a chat box. Only you and your teammate will be able to see the messages sent within your firm.

Before discussing and selecting a price for your firm, in the first two periods, you will have 30 seconds to suggest a price to your teammate. After you suggest a price, you will be able to see the price suggested by your teammate and discuss as well. If none of you suggest a price within those 30 seconds, you will not see a suggested price in your screen. Beginning third period, you will have 15 seconds to suggest a price. After suggesting a price, you will be able to communicate with your teammate about which price to set using a chat box. In the first two periods, you will have 3 minutes to communicate with your teammate and enter the price for your firm.

Starting from the third period, you will have 60 seconds to communicate about prices. You are allowed to post as many messages as you like. There are only two restrictions on messages: you may not post messages which identify yourself (e.g., age, gender, location etc.), and you may not use offensive language. You should use the time to discuss what price you would like to set as a firm.

To familiarize you with how chat works, you will have an opportunity to talk with your teammate and answer some trivia questions (for which you will be paid) at the beginning of period one. You will start suggesting and setting the price for your firm after answering those trivia questions. You will have 5 minutes to complete those trivia questions.

If you and your teammate do not agree on a price before your time is up and select two different prices, the computer will randomly select one of the prices chosen. If neither of you enters a price, the computer will select a price at random between 0 and 100 (no consumers are willing to buy at a price greater than 100), with each integer being equally likely to be your firm's price. If one of you has chosen a price but the other has not, the computer will select the chosen price.

Later in the experiment, you will exchange one person from your firm for one person from another firm. That is, one person will leave your firm for the other firm in the market, and a new person from the other firm will join your firm.

Consider the following examples:

Example 1

If you both agree on a price and enter the price to be 75, your firm's price will be set at 75.

Example 2

Suppose you and your teammate disagree and set prices of 70 and 80, respectively. The computer will randomly select 70 with 50% probability or 80 with 50% probability. Whichever price it selects will be your firm's price.

Example 3

If none of you choose a price within the given time, the computer will randomly select 72 as your firm's price. Again, the random price can be anything from 0–100.

Your teammate will stay the same from period to period. When your teammate changes, you will be notified several periods in advance and given further instructions.

Duration

There will be at least 40 periods in the experiment; after the 40th period, there is a 5/6 probability that the experiment will end. To understand how this works in practice, imagine that the computer throws a die at the end of each period after the 40th. If it rolls a 6, the experiment continues for another period; if it rolls any other number, the experiment will end. Upon completion of the experiment, you will complete a short questionnaire, parts of which you will be paid for.

At the end of the experiment, you will be told of the sum of profits made during the experiment, which will be your payment. Suppose your firm makes a profit of 200,000 ECUs that means both the employees in your firm will get 200,000 ECUs each. You will receive $1 for every 15,000 ECUs you earn during the experiment. You will also receive $7 for participating in the experiment.

Instructions – 4 Firms

This is an experiment in the economics of market decision making. The instructions are simple, and if you follow them carefully and make good decisions you may earn a **CONSIDERABLE AMOUNT OF MONEY** which will be **PAID TO YOU IN CASH** at the end of the experiment.

Markets

In this experiment, you will act as part of a firm, which is in a market with three other firms. The firms produce some good and there are no costs of producing this good. This market is made up of 200 identical consumers, each of whom wants to purchase one unit of the good at the lowest price. The consumers will pay as much as 100 Experimental Currency Units (ECUs) for a unit of the good. This means that your firm can choose any price from 0 to 100, including 0 and 100.

In each market there will be four firms. You will be assigned the role of either Firm Red, Firm Blue, Firm Green or Firm Yellow. Each firm will be able to supply to 200 consumers. The market will operate as follows. In the beginning of each period, all firms will set their selling prices. If only one firm sets the lowest price, then the firm who set the lowest price will sell its capacity at the selected price, and the other firms will not sell to any consumers. If more than one firm set the lowest price, then they will split the available consumers evenly. At the end of each period, all the firms are informed of their own price as well as the prices of all firms in the market.

In order to fix ideas, consider the following examples:

Example 1

Suppose that the four firms choose the following prices: Firm Red sets a price of 75 ECUs, firm Blue sets a price of 80 ECUs, firm Green sets a price of 85 ECUs, and firm Yellow sets a price of 90 ECUs. Firm Red set the lowest price and sells to all 200 consumers at a price of 75 ECUs, making a profit of 15,000 ECUs. Firm Blue, Green and Yellow therefore will not sell to any consumers and makes 0 ECUs.

Example 2

Suppose that the four firms choose the following prices: Firm Red and firm Blue both set a price of 70 ECUs, firm Green and firm Yellow both set a price of 80 ECUs. Given that firms Red and Blue set the lowest price and have the same price, they will share the available consumers equally. Hence, both firms will sell 100 units at a price of 70 ECUs each unit, making profits of 7,000 ECUs. Firm Green and firm Yellow will not sell to any consumers and make 0 ECUs.

Example 3

Suppose that the four firms choose the following prices: Firm Red sets a price of 3 ECUs, firm Blue sets a price of 80 ECUs, firm Green and firm Yellow sets a price of 90 ECUs. Firm Red set the lowest price and sells to all 200 consumers at a price of 3 ECUs, making a profit of 600 ECUs. Firm Blue, Green and Yellow therefore will not sell to any consumers and makes 0 ECUs.

Example 4

Suppose that all the firms set a price of 80 ECUs. Given that the firms set the same price, they will share the available consumers equally. Hence, all firms will sell 50 units at a price of 80 ECUs each unit, therefore making profits of 4,000 ECUs.

Firms

In every period, you will be paired with another subject, and the two of you will act as a firm. You will each be assigned a unique ID, and you will be able to discuss pricing strategy with your teammate using a chat box. Only you and your teammate will be able to see the messages sent within your firm.

Before discussing and selecting a price for your firm, in the first two periods, you will have 30 seconds to suggest a price to your teammate. After you suggest a price, you will be able to see the price suggested by your teammate and discuss as well. If none of you suggest a price within those 30 seconds, you will not see a suggested price in your screen. Beginning third period, you will have 15 seconds to suggest a price. After suggesting a price, you will be able to communicate with your teammate about which price to set using a chat box. In the first two periods, you will have 3 minutes to communicate with your teammate and enter the price for your firm.

Starting from the third period, you will have 60 seconds to communicate about prices. You are allowed to post as many messages as you like. There are only two restrictions on messages: you may not post messages which identify yourself (e.g., age, gender, location etc.), and you may not use offensive language. You should use the time to discuss what price you would like to set as a firm.

To familiarize you with how chat works, you will have an opportunity to talk with your teammate and answer some trivia questions (for which you will be paid) at the beginning of period one. You will start suggesting and setting the price for your firm after answering those trivia questions. You will have 5 minutes to complete those trivia questions.

If you and your teammate do not agree on a price before your time is up and select two different prices, the computer will randomly select one of the prices chosen. If neither of you enters a price, the computer will select a price at random between 0 and 100 (no consumers are willing to buy at a price greater than 100), with each integer being equally likely to be your firm's price. If one of you has chosen a price but the other has not, the computer will select the chosen price.

Later in the experiment, you will exchange one person from your firm for one person from another firm. That is, one person will leave your firm for one of the firms in the market, and a new person from another firm will join your firm.

Consider the following examples:

Example 1

If you both agree on a price and enter the price to be 75, your firm's price will be set at 75.

Example 2

Suppose you and your teammate disagree and set prices of 70 and 80, respectively. The computer will randomly select 70 with 50% probability or 80 with 50% probability. Whichever price it selects will be your firm's price.

Example 3

If none of you choose a price within the given time, the computer will randomly select 72 as your firm's price. Again, the random price can be anything from 0–100.

Your teammate will stay the same from period to period. When your teammate changes, you will be notified several periods in advance and given further instructions.

Duration

There will be at least 40 periods in the experiment; after the 40th period, there is a 5/6 probability that the experiment will end. To understand how this works in practice, imagine that the computer throws a die at the end of each period after the 40th. If it rolls a 6, the experiment continues for another period; if it rolls any other number, the experiment will end. Upon completion of the experiment, you will complete a short questionnaire, parts of which you will be paid for.

At the end of the experiment, you will be told of the sum of profits made during the experiment, which will be your payment. Suppose your firm makes a profit of 200,000 ECUs, that means both the employees in your firm will get 200,000 ECUs each. You will receive $1 for every 5,000 ECUs you earn during the experiment. You will also receive $7 for participating in the experiment.

Trivia and Comprehension Quiz

Trivia Questions

1. Which is the largest state in the U.S. (by area)?
2. What is the third sign of the zodiac?
3. Which natural disaster is measured with a Richter Scale?
4. How many Amendments does the US constitution have?
5. Which planet is known as the red planet?

Comprehension Quiz (2F)

1. "If the firms in the market have a price of 87 and 76; what is the price at which the goods will be sold in the market?"
2. "If your firm's price is 91 and the other firm's price is 95, at what price will the goods be sold?"
3. "If your firm's price is 2 and the other firm's price is 90, what will be the profit of your firm, if there are 200 consumers in the market?"
4. "If your firm's price is 89 and the other firm's price is 89 as well, what will be the profit of your firm, if there are 200 consumers in the market?"
5. "If your firm's price is 71 and the other firm's price is 86, what will be the profit of the other firm?"
6. "If your firm makes 6000 ECUs, how much money (in cents) will you get?"
7. "My team will change every round."
8. "I will be provided with information or new instructions if my team is about to change."

Comprehension Quiz (4F)

1. “If the firms in the market have a price of 87, 92, 76, 97; what is the price at which the goods will be sold in the market?”

2. “If your firm’s price is 91 and the prices of other firms are 95, 96, and 97, at what price will the goods be sold?”

3. “If your firm’s price is 2 and the prices of other firms are 79, 88, and 85, what will be the profit of your firm, if there are 200 consumers in the market?”

4. “If your firm’s price is 89 and the prices of all other firms are 89 as well, what will be the profit of your firm, if there are 400 consumers in the market?”

5. “If your firm’s price is 71 and the other firms in the market have a price of 84, 86, and 86 respectively, what will be the profit of the firms who have the price tied at 86?”

6. “If your firm makes 2000 ECUs, how much money (in cents) will you get?”

7. “My team will change every round.”

8. “I will be provided with information or new instructions if my team is about to change.”

CRT and Wonderlic Questions

CRT Questions

1. A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost (in cents)?

2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?

3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half the lake?

Wonderlic Questions

1. A box of staples has a length of 6 cm, a width of 7 cm, and a volume of 378 cm^3. What is the height of the box?

2. A basketball player averaged 20 points a game over the course of six games. His scores in five of those games were 23, 18, 16, 24, and 27. How many points did he score in the sixth game?

3. A physical education class has three times as many girls as boys. During a class basketball game, the girls average 18 points each, and the class as a whole averages 17 points per person. How many points does each boy score on average?

Demographics, TIPI, and Behavioral Questions

Demographics

1. Age

2. Gender

3. Major

4. Number of Economics classes taken

5. Number of years in the university

6. GPA

TIPI

1. I see myself as: Extraverted, enthusiastic
2. I see myself as: Critical, quarrelsome
3. I see myself as: Dependable, self-disciplined
4. I see myself as: Anxious, easily upset
5. I see myself as: Open to new experiences, complex
6. I see myself as: Reserved, quiet
7. I see myself as: Sympathetic, warm
8. I see myself as: Disorganized, careless
9. I see myself as: Calm, emotionally stable
10. I see myself as: Conventional, uncreative

All TIPI questions had the following choices:

- Disagree strongly
- Disagree moderately
- Disagree a little
- Neither agree nor disagree
- Agree a little
- Agree moderately
- Agree strongly

Behavioral Questions

1. Please tell us, in general, how willing or unwilling you are to take risks. Please use a scale from 0 to 10, where 0 means you are "completely unwilling to take risks" and a 10 means you are "very willing to take risks". You can also use any numbers between 0 and 10 to indicate where you fall on the scale, like 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

2. In comparison to others, are you a person who is generally willing to give up something today in order to benefit from that in the future or are you not willing to do so? Please use a scale from 0 to 10, where a 0 means, "you are completely unwilling to give up something today" and a 10 means "you are very willing to give up something today". You can also use the values in-between to indicate where you fall on the scale.

3. How well does the following statement describe you as a person? As long as I am not convinced otherwise, I assume that people have only the best intentions. Please use a scale from 0 to 10, where 0 means "does not describe me at all" and a 10 means "describes me perfectly". You can also use the values in-between to indicate where you fall on the scale.

4. Imagine the following situation: you are shopping in an unfamiliar city and realize you lost your way. You ask a stranger for directions. The stranger offers to take you with their car to your destination. The ride takes about 20 minutes and costs the stranger about 20 Dollars in total. The stranger does not want money for it. You carry six bottles of wine with you. The cheapest bottle costs 5 Dollars, the most expensive one 30 Dollars. You decide to give one of the bottles to the stranger as a thank-you gift. Which bottle do you give? Respondents can choose from the following options: The bottle for 5, 10, 15, 20, 25, or 30 Dollars.

5. How do you see yourself: Are you a person who is generally willing to punish unfair behavior even if this is costly? Please use a scale from 0 to 10, where 0 means you are

"not willing at all to incur costs to punish unfair behavior" and a 10 means you are "very willing to incur costs to punish unfair behavior". You can also use the values in-between to indicate where you fall on the scale.

GPT-4 Prompt for Chat Classification

The following is the standardized prompt submitted to GPT-4 for each firm-period chat:

> This transcript is from an economic experiment with a [2-firm / 4-firm] market. Subjects in the experiment received the following instruction text prior to participating.
>
> [Instruction files inserted here]
>
> Key experimental features:
>
> - Firms submit prices from 0 to 100.
> - The lowest price in the market wins the round.
> - If firms tie on the lowest price, they share 200 consumers equally.
> - There is no cost to production, and all consumers are computerized.
> - Chat occurs between two teammates within the same firm, not across firms.
> - Players observe all firms' prices after each round.
> - From period 21 onward, some players switch to new firms.
> - Player names reflect colors and numbers (e.g., "Player Red 1") but still refer to teammates.
> - Collusion is not always explicit and may occur through strategies such as raising prices, matching, or planning.
>
> Using the predefined codebook (1a - 3i) described in the main text, label all applicable themes in the firm-period chat below.
>
> Chat transcript: [Insert chat file here.]
>
> Return labels as a comma-separated list (e.g., 2f, 3c). Return "None" if no codes apply.

The instructions for both treatments was dynamically inserted from '.docx' files provided to participants 2F_2E.docx or 4F_2E.docx, depending on treatment. The chat classification codebook (codes 1a – 3i) was introduced earlier in the paper in section 5.2.

Appendix D: Screenshots

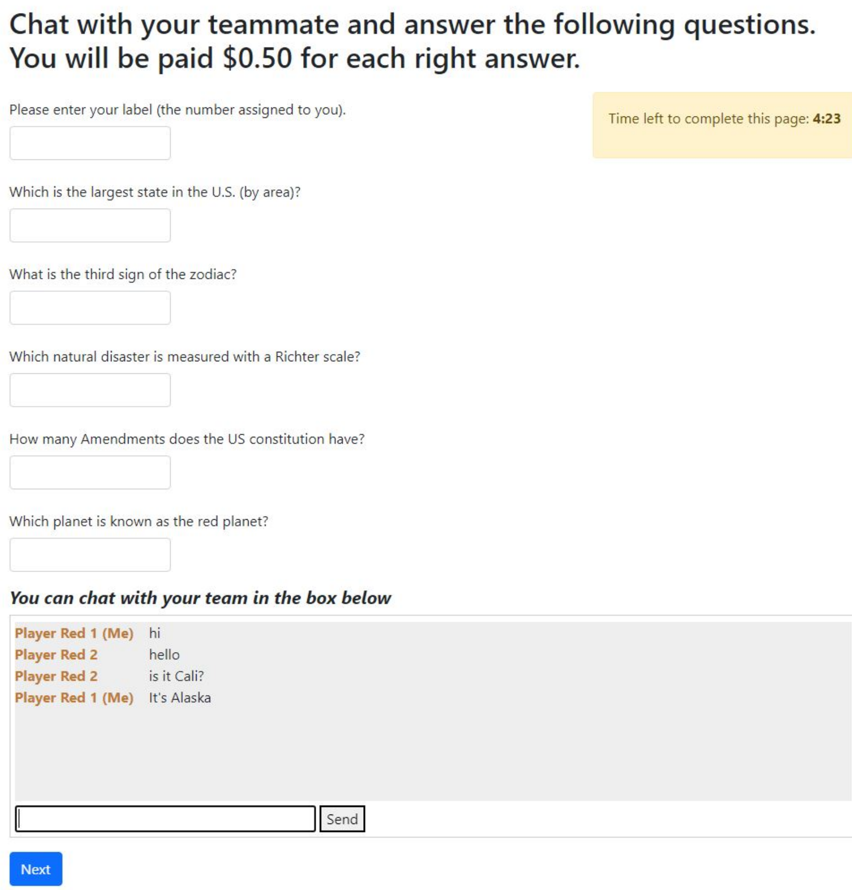

Figure 6: Trivia chat screen before the Bertrand game starts

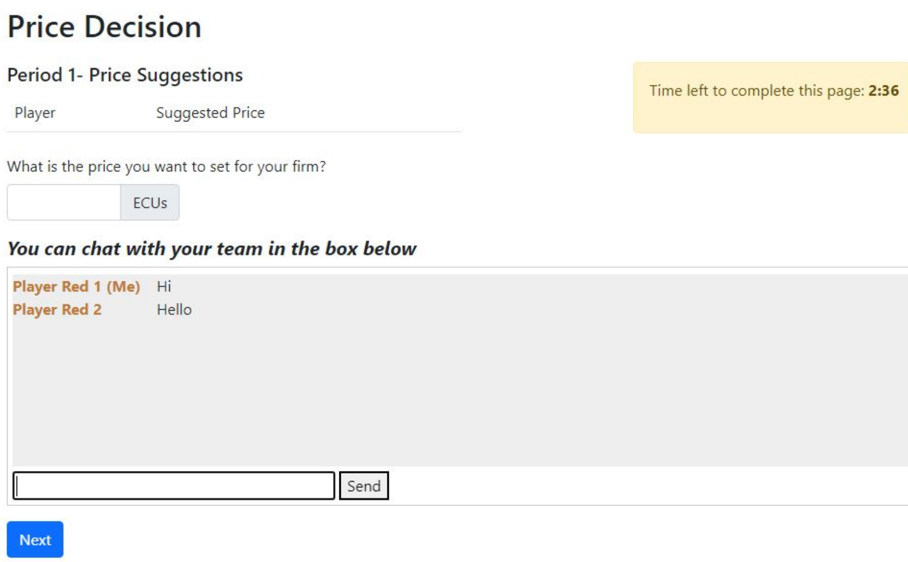

Figure 7: Price Decision page

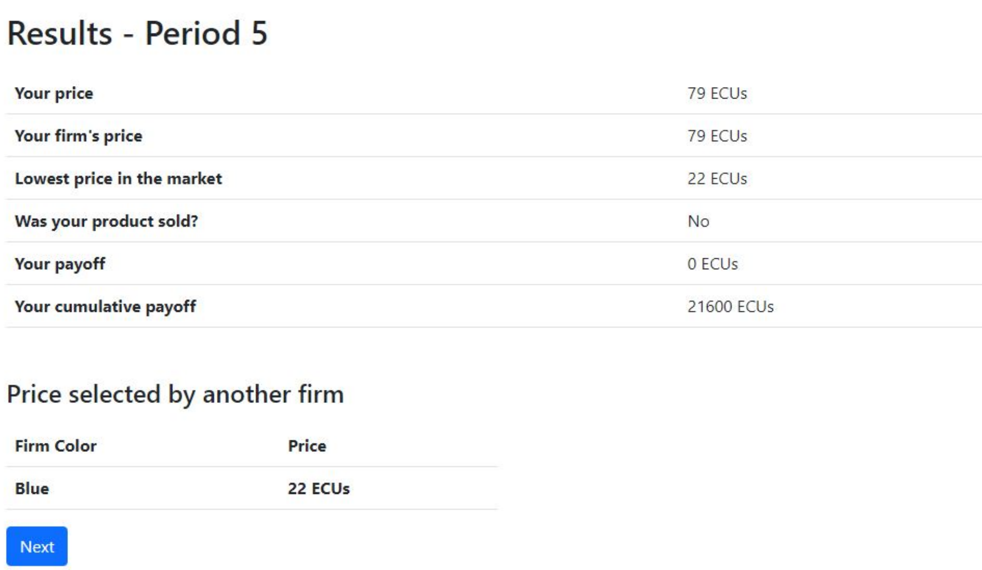

Figure 8: Results page after price decision

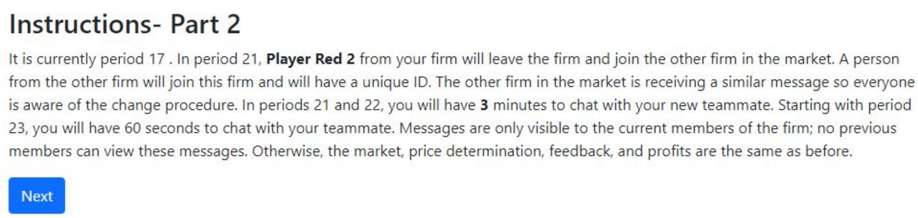

Figure 9: Instructions regarding employee switch before period 17 starts

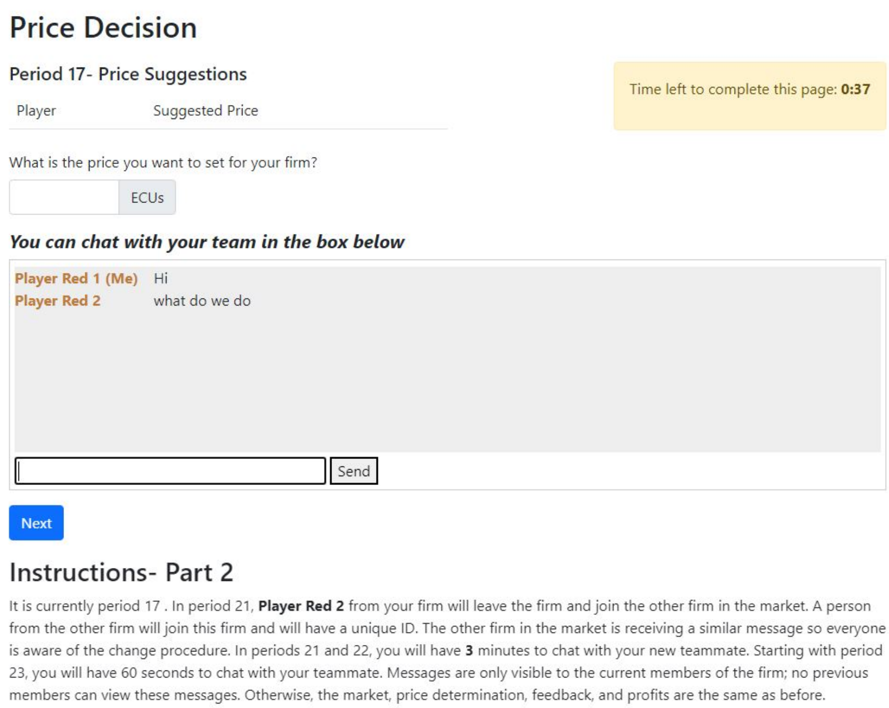

Figure 10: Decision page from period 17-20