Leniency Programs and the Design of Antitrust: Experimental Evidence with Unrestricted Communication

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Abstract

We present experimental evidence on the effectiveness of corporate leniency programs. Our experiment allows subjects to have unrestricted communication. Also, they can apply for leniency after an antitrust investigation has been announced. We find that leniency programs lead to lower prices overall, fewer cartels, but higher cartel prices. Having a few profound rather than many superficial investigations leads to fewer cartels, but does not significantly affect market prices. Cartels that are prosecuted and fined are highly likely to continue to set high prices after their prosecution, even without further communication.

JEL Classification Codes: C92, L41.

Keywords: Leniency Program, Antitrust, Cartels, Experiment.

1 Introduction

One of the main tasks of antitrust authorities is to fight cartels. Leniency programs can be helpful in this respect. In such programs, an Antitrust Authority (AA henceforth) offers a fine reduction to firms that report a cartel of which they are a member. Leniency programs have been successful in both the European Union and United States (see e.g. Motta, 2004, and Spagnolo, 2008) in the sense that many cartels have been detected after leniency applications. Still, this apparent success may also be due to an increase in cartel activity. As there is no information on undetected cartels, it is hard to assess this empirically.[1] Experimental methods may shed some light on this.

In this paper, we report on such a laboratory experiment. We study price-setting oligopolies that interact repeatedly. Different from earlier work in such a setting (most notably Hinloopen and Soetevent, 2008, and Bigoni et al., 2009), we allow for unrestricted communication among participants. Moreover, we allow firms to apply for leniency after an antitrust investigation has been announced.

We believe that both extensions are important steps to bring leniency experiments closer to reality. First, real-world cartel members can freely communicate, rather than having to use the restrictive communication structure common in many experiments. Such unrestricted communication may be an important tool in building trust and determining collusive strategies. Second, many real-world leniency applications only occur after an AA has announced an investigation.[2] Note that this is also a crucial aspect in the theoretical model of Motta and Polo (2003). In our experiment the AA therefore first announces whether it has started

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[1]Miller (2009) and Brenner (2009) are the most sophisticated empirical studies for the US and the EU, respectively.

[2]Our sources within the NMa (the Dutch antitrust authority) note that some 70% of leniency applications occur after an investigation has been announced. Sources within the Swiss antitrust authority cite similar numbers.

an investigation. Only then the cartel members have to decide whether to apply for leniency.

In a nutshell, our experiment is as follows. Subjects play a homogeneous Bertrand duopoly for at least 20 periods. In each period they first decide whether to communicate. If both decide to do so unrestricted communication takes place. Second, subjects choose prices. Third, an antitrust investigation is opened with some probability and subjects learn about this. Fourth, subjects can apply for leniency. Fifth, if an investigation was started and there was no application for leniency, there is some probability that the AA finds evidence. If there is a leniency application, it finds evidence for sure. If the AA finds evidence, fines are imposed.

We run a treatment *Superficial*, in which the probability of investigation is 75% and conditional on this the probability of finding evidence is 20%, and a treatment *Profound*, where these respective probabilities are 20% and 75%. In both treatments the ex ante probability of cartel detection therefore is 15%. In Profound, the AA thus effectively opens a small number of profound investigations, while in Superficial, it conducts a larger number of superficial investigations. We compare these treatments to an *Antitrust* treatment, which has no leniency program, and a *Benchmark* treatment that does not even have an AA.

The remainder of this paper is structured as follows. In Section 2 we discuss the related literature. Section 3 presents our experimental design, while Section 4 derives theoretical implications. Results are reported in Section 5, in terms of prices, deviations, cartelization, communication, reporting, and fines. Section 6 concludes. In the Appendix we provide the instructions for the Leniency Profound treatment, plus detailed information on market prices set by each duopoly throughout the experiment.

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2   Related Literature

We are not the first to study leniency programs in an experimental setting. In a pioneering contribution, Apesteguia et al. (2007) study a one-shot homogeneous Bertrand triopoly, allowing for unrestricted communication between subjects. They find that a leniency program decreases prices, but does not affect cartel activity. Hinloopen and Soetevent (2008) build on the work of Apesteguia et al. (2007), with three important differences. First, they consider a repeated game. Second, they introduce a positive probability that an AA detects a cartel even if no firm reports. Third, they restrict the extent to which subjects can communicate. The authors study a homogeneous Bertrand triopoly with restricted communication. In particular, each subject can indicate an acceptable price from the set $\{101, 102, \ldots, 110\}$. The intersection of all three price ranges becomes the choice set of a second round of negotiations. That process continues until a unique price is reached or a minute has passed. The price range that results serves as a suggested price. The authors find that prices are lower under a leniency program. Cartel activity is also lower. Moreover, cartels are very short-lived, since almost all cartels are immediately reported to the AA.

Bigoni et al. (2009) study a heterogeneous Bertrand duopoly. After each period, rematching of subjects takes place with probability 15% and cartel members can no longer be prosecuted for earlier cartels. Communication is restricted in that subjects can only indicate their acceptable minimum price. Subjects have the possibility to report a cartel both before and after they learn the price their competitor has set. The authors find fewer cartels under a leniency program, but those that exist are longer lived. Average prices overall are lower under leniency, but average cartel prices are higher.

Somewhat less relevant for our study is Hamaguchi et al. (2009) who focus on the leniency application per se and impose subjects to form a cartel. The authors

find that larger cartels break down sooner, and the level of leniency or number of applicants eligible to receive leniency has no effect.

In our experiment, we try to create an environment that is most susceptible to a cartel. For that reason, we use a repeated homogeneous Bertrand duopoly (see, amongst others, the discussion in Haan et al., 2009). We allow our subjects to engage in unrestricted communication, as in Apestegui et al. (2007), but unlike both Hinloopen and Soetevent (2008) and Bigoni et al. (2009). To our knowledge, we are the first to allow subjects to apply for leniency after they have learned whether the AA has started an antitrust investigation.

3   Experimental Design

We run four treatments: Benchmark, Antitrust, Leniency Profound and Leniency Superficial. We will often refer to the latter two as simply Profound and Superficial. We use stable matchings: every subject plays with the same competitor in all periods. Subjects play at least 20 periods. After that, there is a probability of 20% in each period that the experiment ends.

Our leniency treatments proceed as follows.[3] In stage 1, each subject indicates whether he is willing to communicate by either pressing a 'YES' or a 'NO' button on his computer screen. In stage 2, communication takes place if both players have pressed the 'YES' button in the previous stage. In that case a chat box appears on the screen for a fixed amount of time.[4] A subject that chooses not to communicate in stage 1 never learns the communication decision of the other player. Once communication takes place, subjects have formed a cartel and are thus liable to

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[3]Instructions for Profound are reproduced in the Appendix. These are couched in neutral terms to avoid normative connotations that may be implied by terms like *cartel* or *Antitrust Authority*. Instructions for other treatments are similar and available upon request.

[4]Whenever communication occurred for the first time, we gave subjects 90 seconds to chat. When they choose to communicate with a cartel already in place, we gave them 45 seconds. When they communicated to re-establish a cartel, they had 60 seconds. Subjects were always aware of this as a countdown timer also appeared on the chat screen.

prosecution.[5] A cartel that is in place only terminates if it is detected by the AA or if it is reported by a cartel member. Subjects can thus be prosecuted not only for communication that occurred in this period, but also for communication that occurred in the past but was not yet discovered.

In stage 3, subjects choose prices from the set $\{1, 2, \ldots, p_{max}\}$, where we set $p_{max} = 10$. Costs are normalized to zero. The subject with the lowest price captures the entire market and makes profits equal to his price. If both subjects set the same price, they share the market. After prices are set, subjects learn the price chosen by their competitor.

In stage 4, the AA opens an investigation with probability α. Subjects learn whether an investigation has opened. If there was communication, they then decide whether to report this by pressing a 'REPORT' or a 'NOT REPORT' button. Reporting costs $c_r = 0.5$.[6] Without reports, the AA detects a cartel with probability p. With reports, it discovers a cartel for sure. A cartel member that is caught pays fine $F = 9$. A subject that reports the cartel pays a reduced fine $R_a = 1$ if an investigation has started, and $R_b = 0$ if that is not the case. This is in line with e.g. European practice, where reporting may lead to full leniency, but only if the AA had not started an investigation yet. Only the first subject to report receives a reduced fine. For experimental simplicity, if both report, each receives half of the fine reduction, leaving them with a fine of 5 with an investigation, and a fine of 4.5 without one. After this stage, subjects learn the reporting decisions of their competitor.

Subjects thus also have the option to report when there is no investigation. Reports can therefore be used as a punishment device after a deviation from a collusive agreement, see Spagnolo (2000) and Ellis and Wilson (2001). We use

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[5]Gillet et al. (2011) note that the formation of a cartel is illegal in most countries, regardless of whether firms stick to the cartel agreement.

[6]We include these to make subjects aware of their reporting decision. If applying for leniency would be costless, subjects could apply without considering the consequences of their actions.

fixed fines in our experiment, different from practice and most other experiments[7] where fines are a percentage of revenues. Again, this is for simplicity. It also allows us to use a more natural range of prices.

In Profound the probability of an investigation is $\alpha = 0.20$ and, conditional on this, the probability of an investigation being successful is $p = 0.75$. In Superficial $\alpha = 0.75$ and $p = 0.20$. Thus, in Profound the AA opens a relatively small number of profound investigations, while in Superficial a relatively large number of superficial investigations are opened.[8] In our Antitrust treatment, subjects do not have the option to report. It thus consists of the stages 1-3 above with the probability of cartel detection set at 15%. Our Benchmark treatment has stages 1-3, but with a probability of cartel detection of 0%. In this treatment, subjects can thus freely form cartels without the risk of being fined.

4 Theory

In this section we give a theoretical treatment of our experiment, along the lines of Motta and Polo (2003). We solve the leniency model for general parameter values.

The reporting rule is an explicit part of the collusive strategies. Unilateral deviations from a cartel agreement can thus be twofold: a firm can deviate by setting a lower price, and it can deviate from the reporting agreement. As in Motta and Polo (2003) we assume that a cartel that has been convicted but did not defect will immediately resume its collusive behavior. Firms use trigger strategies, and thus revert to the competitive price after any defection. In our case the competitive price is $p^N = 1$.

Suppose firms play **collude and reveal** (CR): they always set the monopoly

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[7]See however Bigoni et al. (2009).

[8]Note that, without reports, the ex ante probability of a convinction equals $\alpha p = 0.15$ in both cases. This is in line with Combe et al. (2008) and Bryant and Eckard (1991), who report empirical evidence of a conviction probability between 12.9%-13.3% in the EU and 13%-17% in the US, respectively.

price and report their cartel after an investigation has opened. Each firm then receives collusive profit π^m in each period. With probability α an investigation is opened and each firm reports, incurring reporting cost c_r and expected fine $\frac{1}{2}(R_a + F)$. Defining V_{CR} as each firm's value of playing CR, we thus have

$$V_{CR} = \alpha \left[\pi^m - c_r - \frac{1}{2}(R_a + F) \right] + (1 - \alpha)\pi^m + \delta V_{CR}, \tag{1}$$

which yields

$$V_{CR} = \frac{\pi^m - \alpha \left[c_r + \frac{1}{2}(R_a + F) \right]}{1 - \delta}. \tag{2}$$

Consider a deviation. Clearly, it is never optimal to deviate from the reporting rule. Defecting from the market price yields $2\pi^m - 1$ now, and competitive profits π^N in future periods. After such a deviation both firms will choose to report.[9] The fine is $\frac{1}{2}(R_a + F)$ with probability α, and $\frac{1}{2}(R_b + F)$ with probability $1 - \alpha$. Thus, the payoff associated with the unilateral deviation is

$$V_D = (2\pi^m - 1) - c_r - \frac{1}{2}\{[\alpha R_a + (1 - \alpha)R_b] + F\} + \frac{\delta}{1 - \delta}\pi^N. \tag{3}$$

If firms play **collude and not reveal** (CNR), they always set the monopoly price and do not report after an investigation was opened. With probability α, an investigation is opened. In that case, with probability p the cartel will be convicted and each firm pays F. Defining V_{CNR} as each firm's value of playing CNR,

$$V_{CNR} = \alpha [\pi^m - pF] + (1 - \alpha)\pi^m + \delta V_{CNR}, \tag{4}$$

hence

$$V_{CNR} = \frac{\pi^m - \alpha pF}{1 - \delta}. \tag{5}$$

A deviation from CNR in price again yields V_D given by (3). A firm can only consider a deviation from the reporting rule after it has learned that an investigation is opened. In that case, if no firm defects, each earns

$$V_{NR}|\alpha = p[\pi^m - F + \delta V_{CNR}] + (1 - p)[\pi^m + \delta V_{CNR}], \tag{6}$$

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[9]At least, for the parameter values that we consider.

thus

$$V_{NR}|\alpha = \frac{\pi^m - [1 - \delta(1-\alpha)]\,pF}{1-\delta}. \tag{7}$$

A firm that deviates by reporting pays the reduced fine R_a, and earns π^N in future periods. The value of this deviation thus equals

$$V_R|\alpha = \pi^m - c_r - R_a + \frac{\delta}{1-\delta}\pi^N. \tag{8}$$

	Benchmark	Antitrust	Profound	Superficial
V_{CR}	-	-	19.5	4.38
V_{CNR}	-	-	18.25	18.25
$V_R|\alpha$	-	-	5.5	5.5
$V_{NR}|\alpha$	-	-	12.85	17.8
V_C	25	18.25	-	-
V_D	11	6.78	5.9	5.63

Table 1: Values of different strategies

Table 1 gives the value functions in our experiment, using the parameters that we have implemented. In the non-leniency treatments, the value of being in a cartel is denoted V_C.[10] In Superficial, we have $V_D > V_{CR}$ but $V_D < V_{CNR}$. Firms thus do not have an incentive to defect in price from a collusive agreement in which they agree not to report. Also, $V_R|\alpha < V_{NR}|\alpha$. Hence, they do not have an incentive to deviate from the reporting agreement after an investigation has started. Thus, CNR constitutes an equilibrium. In Profound we have $V_D < V_{CR}$ and $V_D < V_{CNR}$: firms have no incentive to defect in price from a collusive agreement, regardless of the agreement on the reporting rule. After an investigation has started, there is no incentive to defect from a reporting agreement as, as noted above, there is no incentive to defect from an agreement to report, and $V_R|\alpha < V_{NR}|\alpha$, so there is no incentive to defect from an agreement not to report. As $V_{CR} > V_{CNR}$ however, we

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[10]Note that in Benchmark $V_C = \frac{\pi^m}{1-\delta}$ and $V_D = 2\pi^m - 1 + \frac{\delta}{1-\delta}\pi^N$, while in Antitrust $V_C = \frac{\pi^m - \alpha pF}{1-\delta}$ and $V_D = 2\pi^m - 1 + \frac{\delta}{1-\delta}\pi^N - \frac{\alpha pF}{1-\delta(1-\alpha p)}$.

expect firms to play Collude and Reveal.[11] Finally, note that in both Antitrust and Benchmark $V_C > V_D$, so a cartel is stable.

5   Results

The experiment was conducted in early 2011 at the experimental lab at the Faculty of Economics and Business of the University of Groningen. A total of 140 subjects participated, all students at that Faculty. Subjects were randomly assigned to treatments: 36 participated in Benchmark, 34 in Antitrust, 36 in Profound, and 34 in Superficial. Sessions lasted between 45 and 75 minutes. Printed instructions were provided and read aloud. On their computer, subjects first had to answer a number of questions correctly to ensure understanding of the experiment.

Participants were paid their cumulative earnings in euros at a rate of €0.10 per point, including an initial endowment of 70 points. Average earnings were €15.44 and ranged from €8.00 to €21.80. The experiment was programmed in z-Tree (Fischbacher, 2007). Throughout this section, we will use the non-parametric Mann-Whitney U Test (MWU) to test for equality of two populations; all statistical tests reported below are for the relevant no-treatment effect versus the one-sided alternative. We only analyze the first 20 periods of each session.

Unless stated otherwise, we will look at cartels in the legal sense. Legally, the firms are in a cartel whenever there has been communication and subjects have not

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[11]We also need leniency to be non-exploitable (Spagnolo, 2000): it should not be profitable to **Collude and Report Always** (CRA) i.e. to establish a cartel and report it in each period. Doing so yields

$$V_{CRA} = \alpha \left[\pi^m - c_r - \frac{1}{2} \left(R_a + F \right) \right] + (1 - \alpha) \left[\pi^m - c_r - \frac{1}{2} \left(R_b + F \right) \right] + \delta V_{CRA}, \qquad (9)$$

which implies

$$V_{CRA} = \frac{\pi^m - c_r - \frac{1}{2} \left([\alpha R_a + (1 - \alpha) R_b] + F \right)}{1 - \delta}. \qquad (10)$$

Nonexploitability requires $V_{CR} > V_{CRA}$ and $V_{CNR} > V_{CRA}$, hence $\alpha(9p - 0.5) < 5$. This holds in both our leniency treatments.

been fined for this. In some cases, we will also report on cartels in the economic sense. A cartel in the economic sense exists whenever the market price is larger than the competitive price of 1, regardless of communication. With tacit collusion we thus have a cartel in the economic sense, but not in the legal sense. Only cartels in the legal sense can be prosecuted. We will call markets "competitive" whenever there is no cartel in the legal sense, and regardless of the price that firms set.
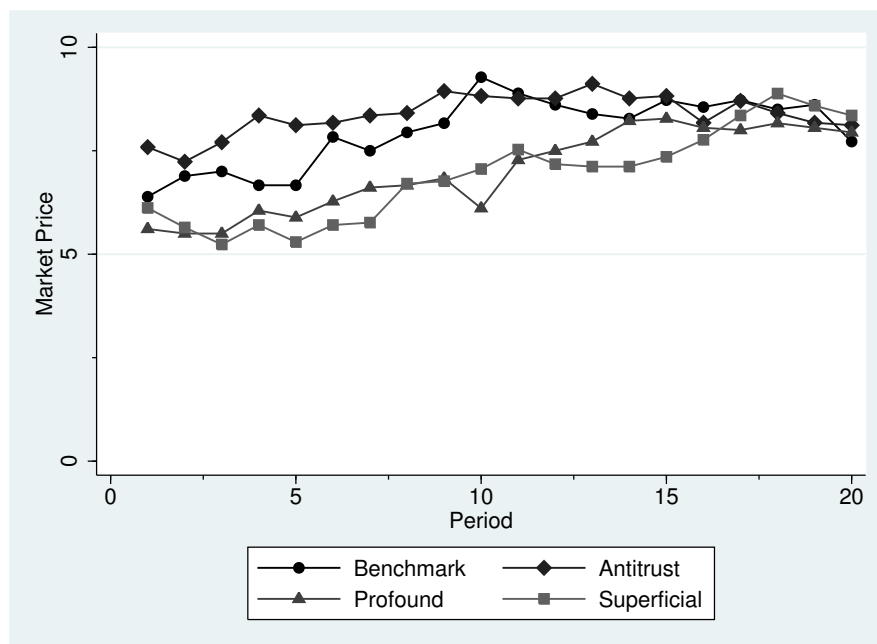

Figure 1: Average market prices per period

5.1 Market Price

Figure 1 shows the average price path[12] for all treatments.[13] Most notably, prices in the Benchmark and Antitrust treatments are higher than those in both leniency treatments, but prices seem to roughly converge in the last 5 periods. Somewhat surprisingly, average prices seem to increase over time, especially in the leniency

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[12]Unless stated otherwise, "prices" refer to market prices, i.e. the lowest price quoted.

[13]Figures for each separate market are given in the Appendix.
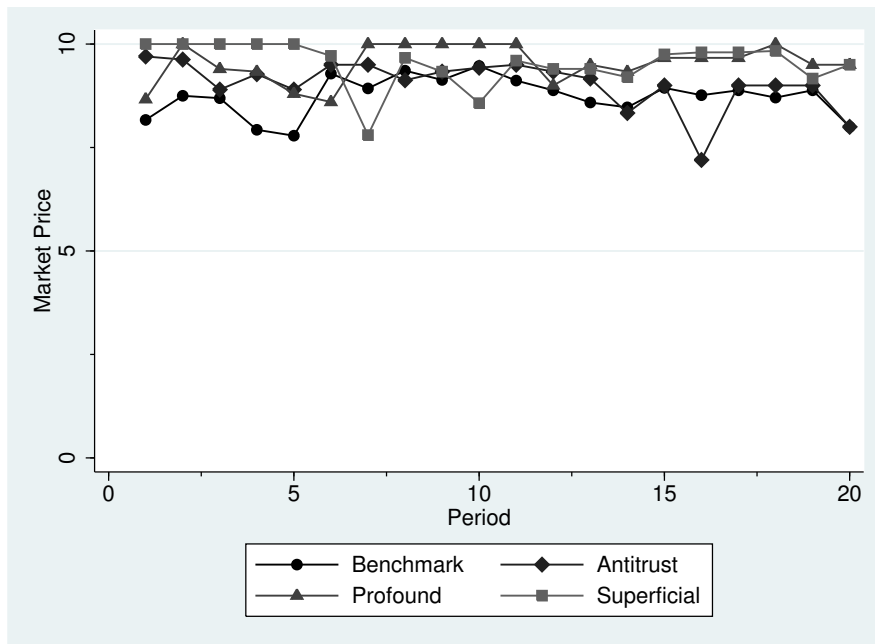
treatments.[14]

Figure 2: Average market prices per period in cartels

In Figures 2 and 3 we further differentiate between cartels (in the legal sense) and competition. Overall, cartel prices are stable and high, but somewhat higher in the leniency treatments, especially in the last 5 periods. Surprisingly, competitive prices increase over time in the leniency treatments and, to a lesser extent, in the Antitrust treatment.

Treatment	All Markets	Cartels	Competition
Benchmark	7.97	8.75	3.24***
Antitrust	8.38	9.15	7.89*
Profound	7.01	9.41	6.48**
Superficial	6.91	9.52	5.68***

* significantly different from cartel price at 5%; ** at 1%; *** at 0.1% (MWU test for equality).

Table 2: Average market price per treatment (across all periods)

[14]Average prices over the first 5 periods are significantly lower than those over the last 5 periods at 5% in Benchmark, Profound, and Superficial. The difference is insignificant in Antitrust.
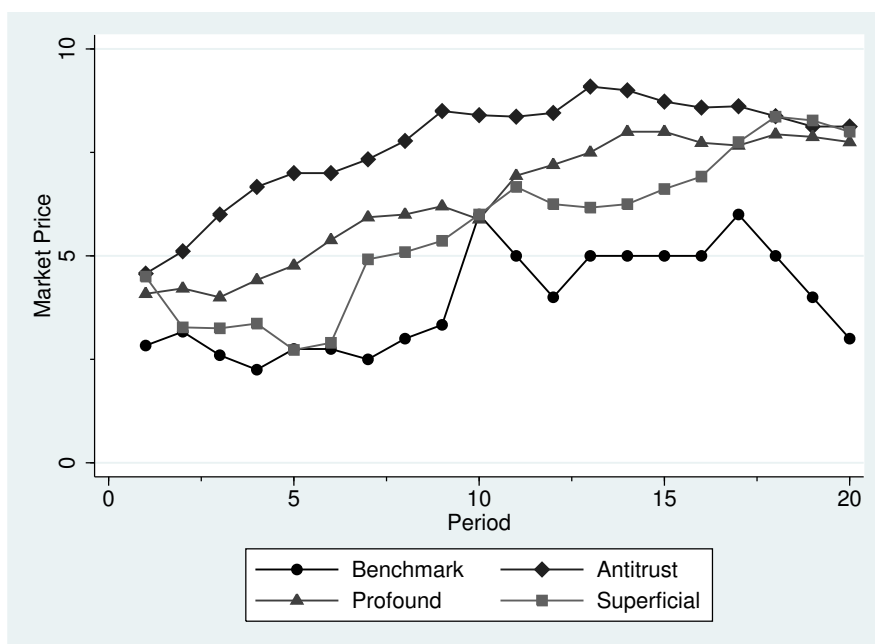
Figure 3: Average market prices per period in competitive markets

Table 2 gives summary statistics. In all treatments average cartel prices are significantly higher than average competition prices. Average overall prices in either leniency treatment are significantly lower than those in Antitrust (at 10%). However, average cartel prices in either leniency treatment are significantly *higher* than in Benchmark.[15] This is in line with Bigoni et al. (2009), but contrary to Hinloopen and Soetevent (2008). In Antitrust, the average cartel price is significantly higher than in Benchmark (at 5%). In other words, in all treatments with the risk of prosecution, average prices are higher than without such a risk. Andersson and Wengström (2007) observe that collusive agreements are more stable when communication is costly, in the sense that prices are higher and there are fewer deviations. Of course, in our case communication only yields *expected* costs in the form of a possible fine. Still, our subjects also seem more committed to a cartel agreement when it is costly to establish one.

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[15]At 5% for Profound, 1% for Superficial.

When we look at prices under competition, we find that the average price is significantly lower in Benchmark than in Antitrust (at 0.1%), Profound (1%), and Superficial (5%). All other differences are not significant.
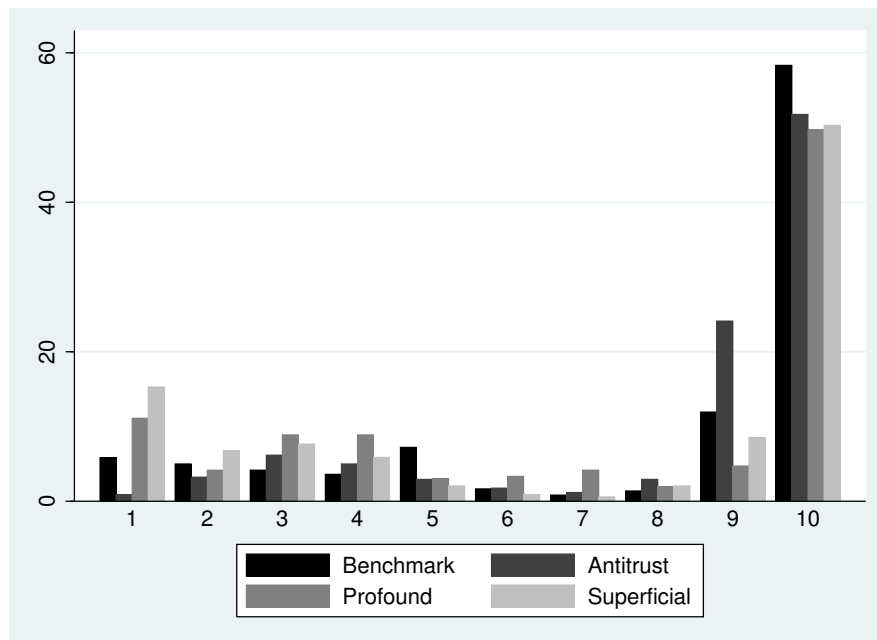

Figure 4: Distribution of market prices (%)

Figure 4 gives the distribution of market prices. It reveals that prices are often equal to 9 or 10, but somewhat less so in the leniency treatments. Market prices of 1 occur more often in the leniency treatments. Figures 5 and 6 differentiate between collusive and competitive market periods, and show that cartels in the legal sense almost always set a price at least equal to 9,[16] while prices in competitive markets are more dispersed.

The observation that competitive prices increase over time may be due to a form of "tacit collusion". After a cartel has been convicted, subjects are fined and start with a clean slate. However, as it turns out, convicted cartels often continue

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[16]In many cases, the price of 9 was explicitly part of the cartel agreement and does not reflect a defection. For some reason, a number of subjects decided that it was a good idea to take turns in setting prices equal to 9 or 10.
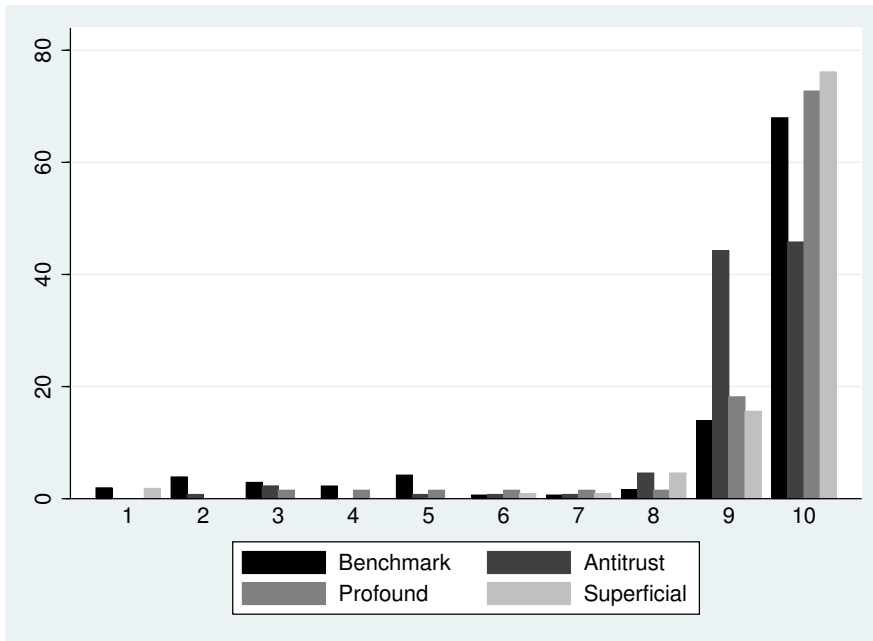
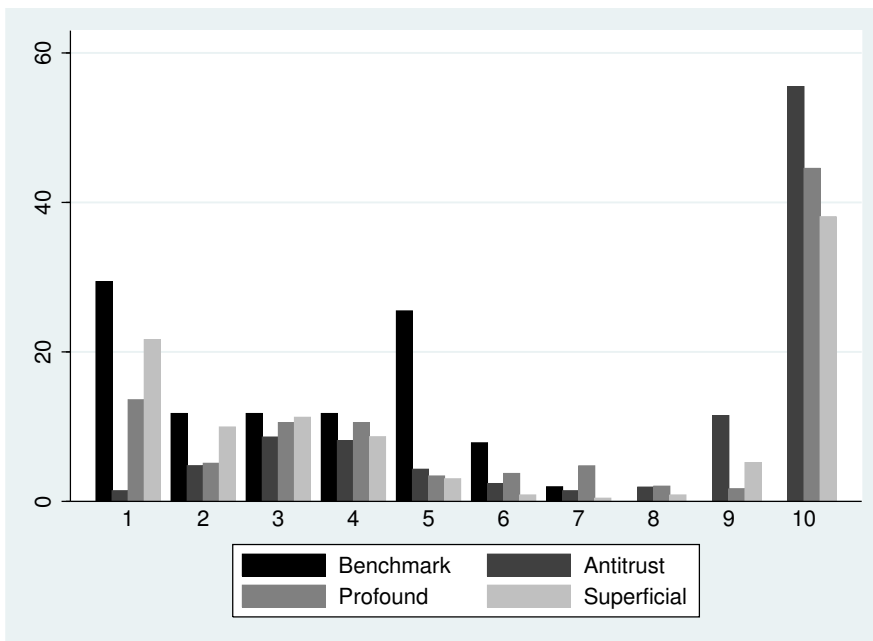Figure 5: Distribution of market prices in cartels (%)

Figure 6: Distribution of market prices in competitive markets (%)

to set a high price without the need for further communication.[17] These subjects are not part of a cartel in the legal sense (since there has been no communication since their last conviction) and are therefore classified as competitive, but they still manage to coordinate on high prices. Over time, the number of such tacit cartels increases, which would explain the increase in average competitive prices observed in Figure 3.
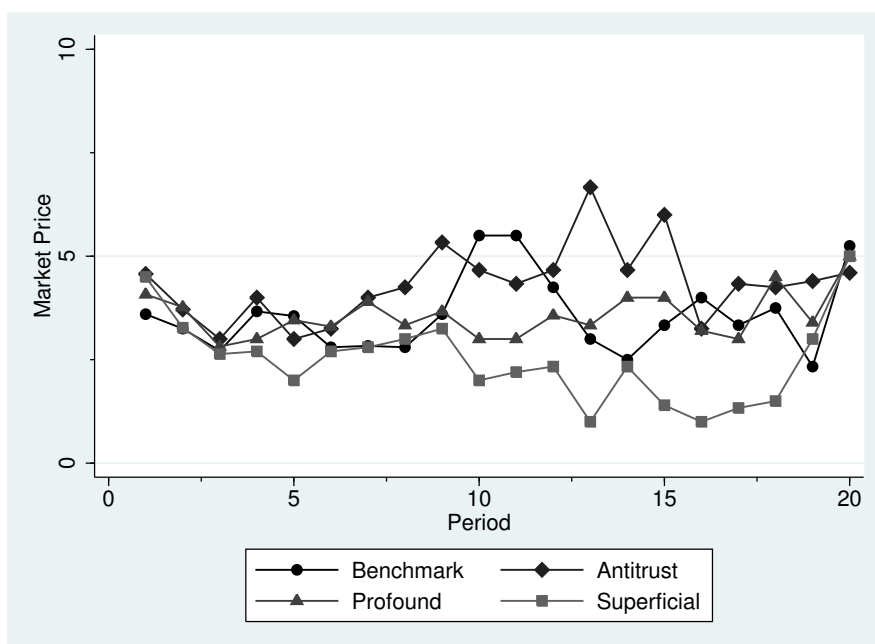

Figure 7: Average prices per period on markets not a strong economic cartel

To see whether this is the case, we study what happens if, for the moment, we extend our definition of an economic cartel somewhat. Suppose that we classify a market as a cartel if the market price equals at least 9. We will refer to such markets as *strong economic cartels*. Arguably, such situations are due to past or present agreements, explicitly or at least tacitly. If the increase in competitive prices over time that we observe in Figure 3 is indeed due to tacit collusion, then

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[17]In a number of cases subjects even explicitly agreed that, should the cartel be detected, they would refrain from further communication but continue to set monopoly prices.

we should not observe such an increase if we define a competitive market as one in which there is no strong economic cartel. Figure 7 shows that this is indeed the case. Average competition prices are now more or less constant over time, although prices in Superficial do exhibit a sharp increase in the last two periods.

Treatment	Price
Benchmark	4.64
Antitrust	4.56
Profound	3.99
Superficial	3.54

Table 3: Average prices on markets not a strong economic cartel (across all periods)

Average prices for markets with no strong economic cartel are given in Table 3. Those in Antitrust are still higher than in both leniency treatments (at 10%), but the absolute difference is much smaller than in the last column of Table 2.

Summing up, we find that introducing a leniency program decreases average prices, although this effect seems to disappear over time. At the same time cartels that are formed under a leniency program are more effective, in the sense that they manage to set a higher price on average. These results do not depend on whether we have many superficial or a few profound investigations.

5.2 Price Deviations

As far as deviations in price from a cartel agreement are concerned, our results differ sharply from those in Hinloopen and Soetevent (2008). These authors find that in 97% of cases at least one subject deviates from a cartel 'agreement' under a leniency program. In that sense, hardly any true cartels are established in their experiment. We rarely observe such deviations: in Profound there are 7 deviations out of 66 cartel agreements, in Superficial 2 out of 109. This is probably due to the unrestricted communication that we have. Participants are apparently less inclined to cheat on an agreement that they explicitly agreed upon, rather than

an agreement that is implied by overlapping price intervals.[18] Cooper and Kühn (2010) argue that unrestricted communication might also be used to renegotiate after a deviation from a cartel agreement has taken place. Several chat sessions among subjects in our experiment confirm that that is the case here.
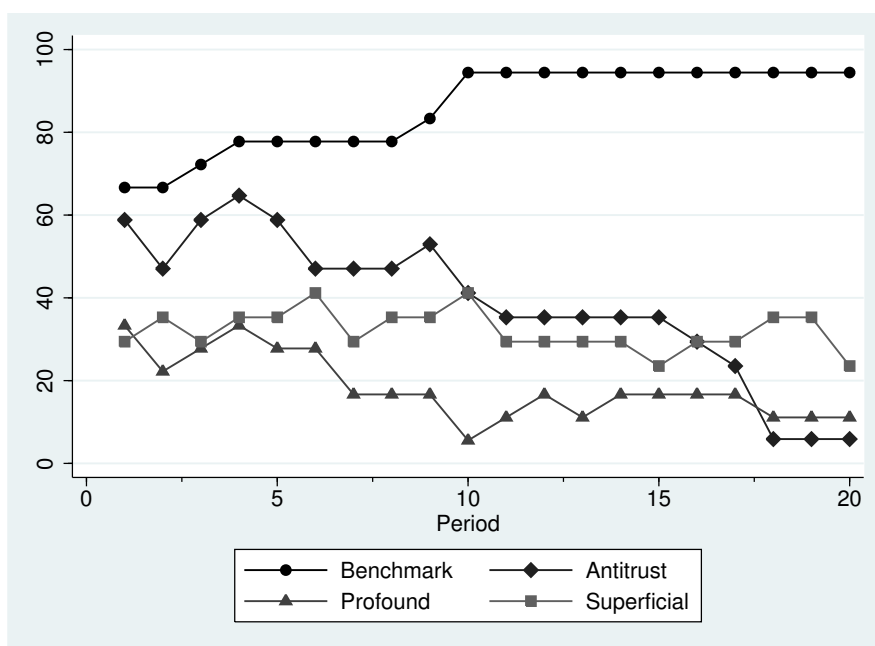
5.3 Cartelization

Figure 8: Markets with a cartel per period (%)

Figure 8 looks at how the cartelization rate (i.e. the percentage of all markets that is a cartel) develops over time. In most periods this rate is lower under either leniency treatment than under Antitrust, but this is no longer true in the final periods. The cartelization rate is decreasing over time in Antitrust and to a lesser extent in Profound, but this is mainly due to the formation of tacit cartels that we discussed above; despite a decrease in the number of cartels, the average prices

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[18]Davis and Holt (1998) also find that direct unrestricted communication between subjects increases the stability of cartels. See further Kühn (2001) and Potters (2009).

increases in those periods, as we saw in Figure 1. In Benchmark we converge to almost full cartelization. To some extent this has to be true by construction: once a cartel is formed in Benchmark it will continue to exist forever as there is no AA to detect it.

Treatment	Overall	Created	Economic
Benchmark	85.8%	71.6%	94.2%
Antitrust	38.5%	11.9%	99.1%
Profound	18.3%	7.1%	88.9%
Superficial	32.1%	9.7%	84.7%

Table 4: Incidence and creation of cartels

The second column in Table 4 gives summary statistics. Overall, the cartelization rate is significantly higher in Benchmark than in any other treatment (at 0.1% in each case). More interestingly, it is significantly lower in Profound than in both Antitrust and Superficial (at 5% and 10%, respectively). There is no significant difference between Antitrust and Superficial.

The third column in Table 4 looks at the cartel creation rate, i.e., the percentage of markets where a cartel is formed out of all markets where a cartel did not exist in the previous period. This rate is significantly higher in Benchmark than in any other treatment (at 0.1% in all cases). It is significantly lower in Profound than in Antitrust (at 10%).

The incidence of economic cartels (markets with a price higher than 1) is given in the fourth column of Table 4. This is significantly lower in both leniency treatments than in Antitrust (both at 1%), consistent with what we observed in Figures 5 and 6. Remarkably, there are even more economic cartels in Antitrust than in Benchmark (at 5%). Other differences are insignificant.

Figure 9 gives the Kaplan-Meier survival rates of cartels in the legal sense. We look at survival rates conditional on a cartel *not* being exogenously discovered by the AA. Hence, cartels that do not survive are only those that collapse due
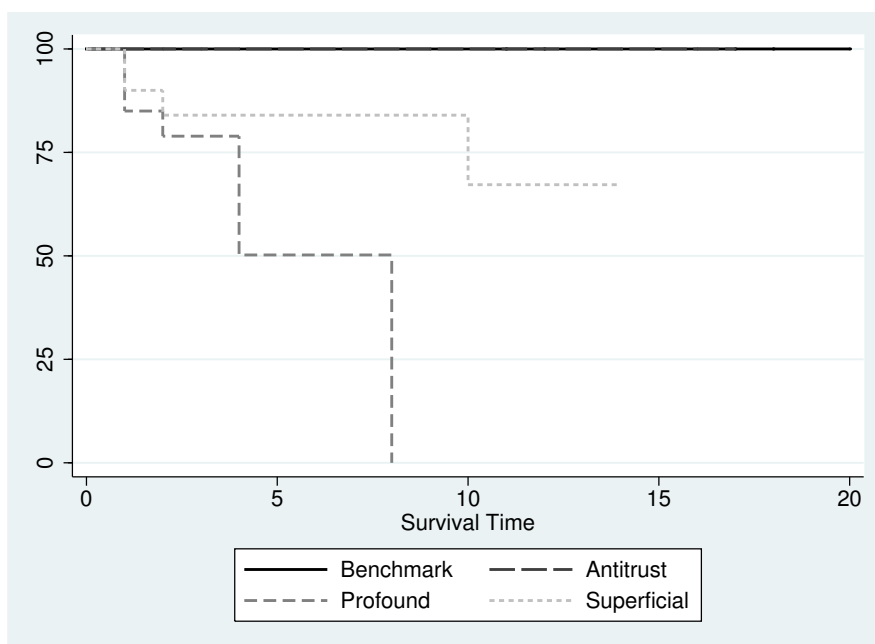
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Figure 9: Kaplan-Meier survival estimates (in %) for cartels in the legal sense

to a leniency application. In the Benchmark and Antitrust treatments, leniency applications are not possible, hence the survival rates in these cases are 100%. From the figure, the expected lifetime of a cartel is significantly longer under Superficial than under Profound (at 5%).

Figure 10 gives the survival rates of economic cartels. Those cartels seem to survive longer under Profound than under Superficial, but the difference is not significant. Remarkably, the survival function in Antitrust lies above that in Benchmark but also this difference is insignificant. Most interestingly, the survival functions in both leniency treatments lie below that in Antitrust.[19]

Summing up, we find that a leniency program decreases the incidence of cartels in the legal sense, though this effect seems to disappear over time. Having a small number of profound investigations yields fewer and shorter-lived cartels than

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[19]Significant at 1% for Superficial and 5% for Profound. The difference between Benchmark and Superficial is significant at 5%, that between Benchmark and Profound is insignificant.
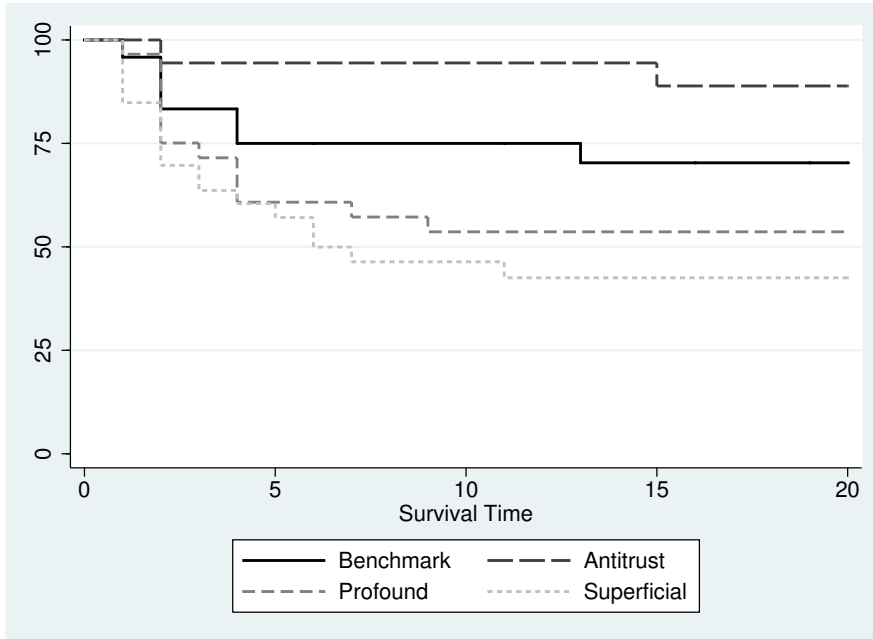
Figure 10: Kaplan-Meier survival estimates (in %) for cartels in the economic sense

having a large number of superficial investigations. Under a leniency program, the incidence of economic cartels also decreases, as does the survival rate of those cartels.

5.4 Communication

Treatment	Overall	No Cartel
Benchmark	46.1%	82.7%
Antitrust	18.4%	22.9%
Profound	27.6%	28.8%
Superficial	26.3%	29.3%

Table 5: Subjects' willingness to communicate (across periods)

Obviously, the presence of cartels is closely related to the willingness of subjects to communicate with their rival. Indeed, both subjects must be willing to do this in order to establish a cartel. Figure 11 gives the communication rate (i.e. the percentage of subjects willing to communicate) for each period. The
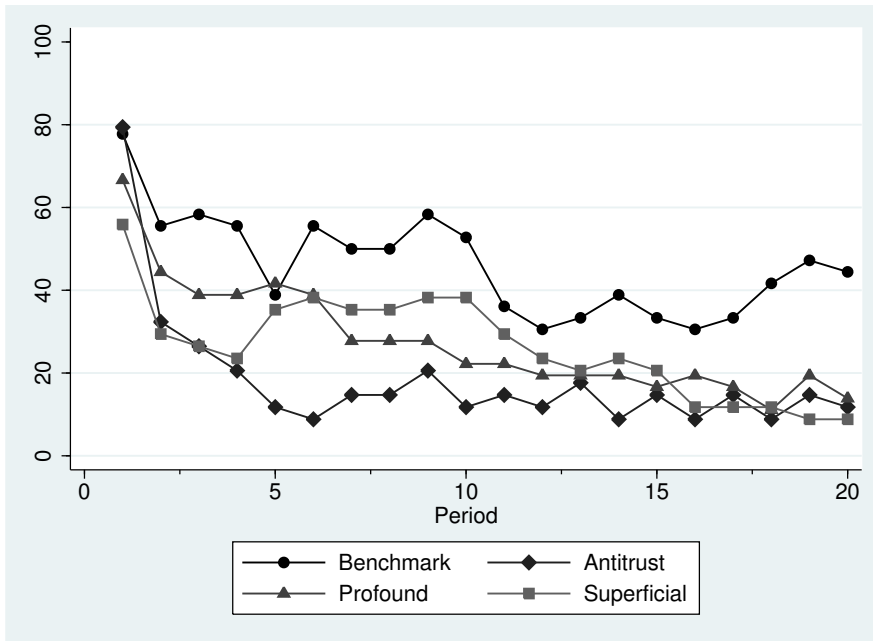
Figure 11: Subjects' willingness to communicate per period (%)

average over all periods is given in the second column of Table 5. Subjects have a significantly higher willingness to communicate in Benchmark than in all other treatments.[20] Moreover, the willingness to communicate is significantly higher in Profound than in Antitrust (at 5%). That is remarkable, since we know from Table 4 that significantly fewer cartels exist in Profound than in Antitrust.

To understand this, note from Figure 12 that in Profound there is a larger number of instances in which only one subject is willing to communicate (which impedes the establishment of a cartel) than in Antitrust. Apparently there were a number of cases in which one of the subjects consistently tried to communicate, while the other consistently chose not to.

When we look at subjects' willingness to communicate in periods in which no cartel exists (the third column of Table 5) we again see that more communication is requested in Benchmark than in any other treatment (at 0.1% in all three cases).

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[20] At 0.1% compared with Antitrust, 5% with Profound and 1% with Superficial.
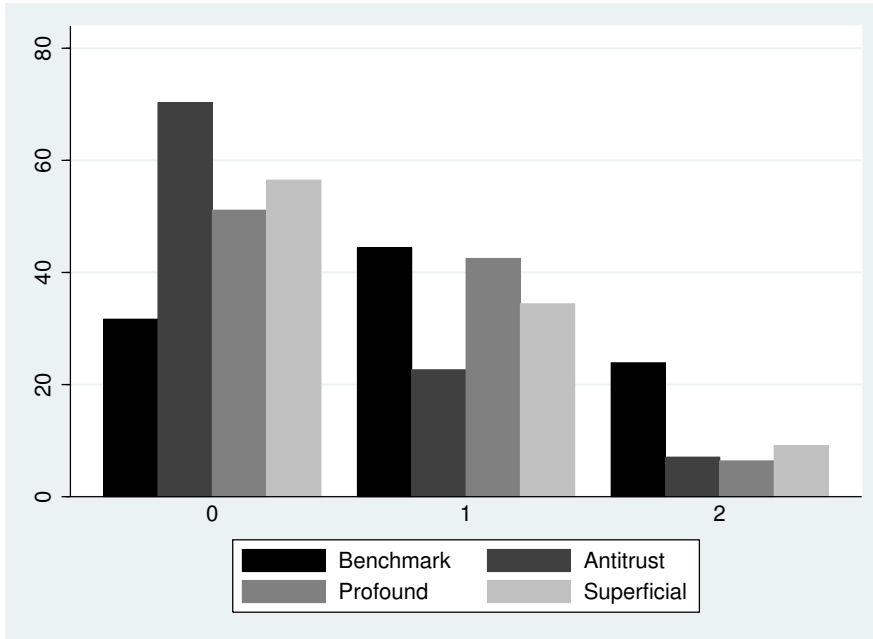
Figure 12: Subjects per group willing to communicate (%)

It is significantly higher in Profound than in Antitrust (at 10%) although we know from Table 4 that fewer new cartels are created in the former case. Again, this is due to there being many instances in Profound where only one subject wants to communicate, see Figure 13. Hence, we obtain the same conclusions if we either consider the willingness to communicate for all periods or only for those periods in which a new cartel can be created.

To better understand the communication decisions, we estimate a discrete-choice model for each treatment. Let $y_{i,t} = 1$ if subject i wants to communicate in period t, and $y_{i,t} = 0$ if he does not. We use the following random-effects binomial logit model of the underlying variable $y_{i,t}^*$:

$$y_{i,t}^* = \beta_0 + \beta_1 \times \text{CartelDetected}_{i,t} + \beta_2 \times \text{CartelReported}_{i,t} + u_i + \epsilon_{i,t} \qquad (11)$$

where $y_{i,t} = 1$ if $y_{i,t}^* > 0$, $y_{i,t} = 0$ if $y_{i,t}^* \leq 0$, $\beta_0, \beta_1, \beta_2$ are coefficients to be estimated, and u_i and $\epsilon_{i,t}$ are independently distributed error terms. CartelDetected$_{i,t}$
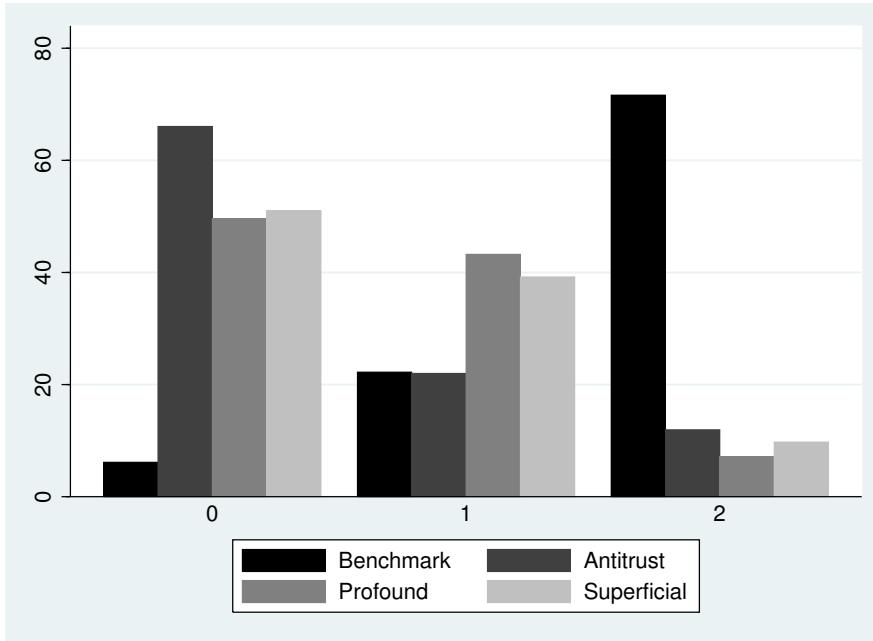
Figure 13: Subjects per group willing to communicate with no cartel in place (%)

is a dummy that equals 1 if a cartel in which i participated has been detected by the AA in the past (i.e. before period t) and 0 otherwise, while CartelReported$_{i,t}$ is a dummy that equals 1 if a cartel in which i participated has been reported in the past and 0 otherwise.

	Benchmark	Antitrust	Profound	Superficial
CartelDetected	−	−5.568***	−4.385***	−3.502***
CartelReported	−	−	−2.896***	−1.490+
constant	2.575*	1.264*	0.422	−0.129
Observations	136	458	628	502

Random-effects binomial logit model of an individual subject's communication decision.
$^{+}$ significant at 10%; * significant at 5%; ** significant at 1%; *** significant at 0.1%.
Only periods are included in which there was no cartel at the start of that period.

Table 6: Subjects' willingness to communicate

In our regressions, we only include periods in which a group was not a cartel at

the beginning of that period, as those are the periods in which communication has an effect on the possibility of being prosecuted. Results are reported in Table 6.[21] Subjects are less inclined to communicate if a cartel in which they participated was detected or reported. Moreover, in both leniency treatments β_1 is significantly smaller than β_2[22], which implies that previous detection has a stronger effect on the willingness to communicate than previous reports. At first sight this result is somewhat surprising. Subjects should expect the cartel to be detected every now and then. The fact that a cartel is indeed detected hence does not yield any new information that would warrant a change in subjects' behavior. However, this result may be (partly) driven by agreements to not communicate but continuing to set high prices after cartel detection.

Summing up, subjects are more inclined to communicate if a leniency program is introduced, but that seems largely driven by cases in which one subject consistently wants to communicate while the other consistently does not. Subjects are less willing to communicate if in the past they have experienced either cartel detection or a cartel being reported, with the effect of detection being stronger.

5.5   Reporting

Table 7 provides information on subjects reporting a cartel. The top panel considers all cartels, the other panels also take into account whether there was a deviation from the cartel (price) agreement. Each panel first considers all observations and then differentiates based on whether an investigation was started.[23]

From the top panel, reporting occurs significantly more often in Profound than in Superficial: in Profound, subjects reported in 10.6% of 132 opportunities, while in Superficial they only reported in 2.3% of 218 opportunities. This difference is

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[21]Adding period dummies does not change the qualitative results.

[22]In Profound at 10%, in Superficial at 5%.

[23]Note that, since we look at decisions of subjects, the number of observations always equals twice the number of cartels.

	# Observations		Percentage reporting	
Reporting	Profound	Superficial	Profound	Superficial
Overall	132	218	10.6%	2.3%*
No investigation	102	50	5.9%	6.0%
Investigation	30	168	26.7%	1.2%+
No deviation from cartel agreement				
Overall	118	214	8.5%	1.4%*
No investigation	94	48	4.3%	2.1%
Investigation	24	166	25.0%	1.2%+
At least one subject deviated				
Overall	14	4	28.6%	50.0%
No investigation	8	2	25.0%	100.0%
Investigation	6	2	33.3%	0.0%

+ significantly different from Profound at 10%, * at 5% (MWU test for equality).

Table 7: Percentage of subjects reporting the cartel in both leniency treatments

entirely driven by cases in which an investigation was opened. From the middle panel, the same is true for cases without a deviation. Note that to some extent this is consistent with our theoretical analysis in Section 4, where we predicted that subjects choose not to report after an investigation is started in Superficial, but to report in Profound.[24] The number of deviations (bottom panel) is too low to yield any statistically significant results.

	# Groups		Percentage	
Strategy when investigated	Profound	Superficial	Profound	Superficial
Report	2	0	15.4%	0.0%
Not report	9	11	69.2%	73.3%
Unknown	2	4	15.4%	26.7%
Never a cartel	5	2		

Table 8: Reporting decisions agreed upon by subjects

Table 8 examines whether subjects explicitly agree to a reporting strategy.[25]

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[24]As a robustness check we also did this analysis for the number of cartels being reported rather than the number of subjects reporting a cartel, but this yields the same qualitative conclusions.

[25]Some groups did not discuss this immediately. Yet, if they did in a later period, we also consider the group to be playing according to that strategy.

In Profound only 2 groups explicitly agree to report the cartel as soon as an investigation opens. All other groups in this treatment explicitly agree not to do so, or do not discuss the reporting decision. In 5 cases, there was never a cartel and hence never any discussion on this. Apparently, most subjects consider it a breach of trust if they would report the cartel. This is confirmed by several chat sessions, and by the fact that in Profound we still find reporting rates much lower than the theoretical prediction of 100%.

5.6 Fines

Average Fines	Antitrust	Profound	Superficial
Overall	1.31	2.02	1.33^+
No investigation	–	0.35	0.36
Investigation	–	7.67	1.62^{***}

$^+$ significantly different from Profound at 10%, *** at 0.1% (MWU test for equality).

Table 9: Average total fine paid by each subject

Table 9 shows that the average amount of fines collected is significantly higher in Profound than in Superficial. This is entirely driven by fines collected after an investigation is opened, which is not surprising given the results in the previous subsection. Thus, if the effectiveness of an AA is assessed by the level of fines collected, it can better open a few profound rather many superficial investigations.

6 Conclusion

This paper presented new experimental evidence on the effectiveness of corporate leniency programs. In our experiment, subjects play a repeated game, can have unrestricted communication, and can apply for leniency after an antitrust investigation has been announced. We believe that these three elements are important in bringing leniency experiments closer to reality.

Our results suggest that leniency programs are effective in the sense that they lead to lower prices overall. Although fewer cartels are formed under leniency, those that are formed set high prices. Having a few profound rather than many superficial investigations leads to fewer cartels, but this does not have a significant effect on market prices. Most disturbingly for antitrust authorities, our results suggest that cartels that are prosecuted and fined are highly likely to continue to set high prices after their prosecution, even without further communication.

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Appendix

Instructions Leniency Profound

Decision-making in a market

You are going to participate in an experiment on decision-making in a market. The experiment lasts for at least 20 periods.

You will play with one other person, chosen at random. Together, you and that other player form a group. You will never learn who the other player is. In each period, you will play with the same player. The other player will always face the exact same decisions with the exact same consequences as you do.

In this experiment you can earn points. The number of points you earn depends on the decisions made by you and those made by the other player. At the beginning of the experiment, you receive 70 points in your account. At the end of each period, the points that you earned in that period will be added to your account. At the end of the experiment the number of points in your account will be converted to euros, at a rate of €0.10 per point.

We will first read the instructions aloud. Then you will have time to read them on your own. After that, there is the possibility to ask questions individually. Please refrain from talking during the entire experiment.

Instructions
In this market you and the other player choose prices in a number of periods. In each period you can earn points. However, based on your decisions and those of the other player, you may also lose points.

Step 1: communication decision
Every period starts with the question whether you want to communicate with the other player. Communication entails a computer chat with the other player. If you want to communicate press "YES", if you do not want to communicate press "NO". Only if both players press "YES", communication takes place and you proceed to step 2. Otherwise, you proceed to step 3.

Step 2: communication
If both players have chosen to communicate in step 1, a chat box will appear on your screen. You can discuss anything you want with the other player. However, you are not allowed to identify yourself by name, number, gender, appearance, or in any other way. If you do, you will not receive any payment after the experiment. You are only allowed to communicate in English. A timer in the top right corner of the screen will inform you of the amount of time you have left.

Step 3: pricing decision

Both players must choose one of the following prices:

$$1, 2, 3, 4, 5, 6, 7, 8, 9, 10.$$

You receive the following number of points:

$$\text{points received} = \begin{cases} \text{your price} & \text{if your price is lower than the} \\ & \text{price chosen by the other player;} \\ \text{your price / 2} & \text{if your price is the same as the price chosen by} \\ & \text{the other player;} \\ 0 & \text{if your price is higher than the} \\ & \text{price chosen by the other player.} \end{cases}$$

After both players have made their decision, you learn the price chosen by the other player. The number of points you have received will also be displayed.

Step 4: reporting decision

There is an outside party that may take points from you if he discovers that you have communicated. With some probability he detects this by himself, but he will also discover this if the communication is reported to him, either by you or by the other player. This applies to communication that took place in this period, but also to communication that took place in a previous period and that has not yet been discovered. We will refer to this as *undiscovered communication*. If communication is discovered, past communication can no longer lead to a future loss of points: there is no longer any undiscovered communication.

Examples

- Suppose you are in period 2. You did not communicate in period 1, and you also do not communicate in period 2. Hence, there is no undiscovered communication.

- Suppose you are in period 2. You did communicate in period 1, this communication was discovered, and you do not communicate in period 2. Hence, there is no undiscovered communication.

- Suppose you are in period 2. You did not communicate in period 1, but you do communicate in period 2. Hence, there is undiscovered communication.

- Suppose you are in period 2. You did communicate in period 1, this communication was not discovered, and you do not communicate in period 2. Hence, there is undiscovered communication.

If there is **no** undiscovered communication, you move to step 5. If there **is** undiscovered communication, there are two possibilities. With a probability of 20%, the outside party starts an investigation, and you move to step 4a. With a probability of 80%, the outside party does not start an investigation and you move to step 4b. You will be informed about this. In both cases, you must decide whether or not you want to report communication. You report by pushing the "REPORT" button, otherwise you push the "NOT REPORT" button. After both players have made their decision, you learn the decision made by the other player.

Step 4a (probability: 20%)
In this case, the outside party **has** started an investigation. Reporting will cost you 0.5 points. In addition to this:

- If you press "REPORT" and the other player presses "NOT REPORT", you lose **1** point and the other player loses **9** points.

- If you press "NOT REPORT" and the other player presses "REPORT", you lose **9** points and the other player loses **1** point.

- If both you and the other player press "REPORT", you both lose **5** points.

- If both you and the other player press "NOT REPORT", the outside party will nevertheless detect your communication with a probability of 75%. In that case you both lose **9** points. With a probability of 25% the outside party will not detect your communication and you both lose **no** points.

Step 4b (probability: 80%)
In this case, the outside party **has not** started an investigation. Reporting will cost you 0.5 points. In addition to this:

- If you press "REPORT" and the other player presses "NOT REPORT", you lose **0** points and the other player loses **9** points.

- If you press "NOT REPORT" and the other player presses "REPORT", you lose **9** points and the other player loses **0** points.

- If both you and the other player press "REPORT", you both lose **4.5** points.

- If both you and the other player press "NOT REPORT", the outside party will not detect your communication and you both lose **no** points.

Please note that if there is undiscovered communication already, then communicating again has no effect on the probability of investigation, and it also has no effect on the number of points that will be deducted if communication is discovered. In other words: it is only important *whether* there is undiscovered communication, **not** *how much* undiscovered communication there is.

Figure 1 gives a schematic representation of when you lose points. Please make sure that you understand this figure and also make sure that it is in line with the instructions above.

Example 1. Suppose that there is undiscovered communication. You choose a price of 6, and the other player chooses a price of 7. You thus receive 6 points, while the other player receives 0 points. In step 4, it turns out that the outside party does not start an investigation, so you move to step 4b. There, you press the "NOT REPORT" button, while the other player presses "REPORT". Hence, you lose 9 points. The other player loses 0 points, but has to incur the 0.5 points in reporting cost. After this period, your account will change by $6 - 9 = -3$ points. The account of the other player will change by $0 - 0 - 0.5 = -0.5$ points.
Example 2. Suppose that there is no undiscovered communication. You choose a price of 6, and the other player chooses a price of 6. You thus receive 3 points, while the other player receives 3 points. As there is no undiscovered communication, you move directly to step 5, and both players lose no points. After this period, your account will change by $3 - 0 = 3$ points.

The account of the other player will also change by 3 − 0 = 3 points.

Step 5: summary
In this step you receive an overview of how you have fared in this period: how many points you received, how many points were deducted, and the current state of your account. Throughout the experiment, there will also be a box on your screen where you can observe the decisions made by you and the other player in each previous period.

End of experiment
In the first 19 periods, step 5 is always followed by step 1 of the next period. From period 20 onwards, the experiment ends with a 20% probability at the end of each period. With a probability of 80%, step 1 of a next period starts.

You receive a message on your screen if no further period will take place. At the end of the experiment, the number of points in your account will be converted at a rate of €0.10 per point. Before being paid in private, you have to hand in the instructions.

After the experiment, please do not discuss the exact content with anyone, including people who did not participate.

Please refrain from talking throughout the experiment.

THANK YOU VERY MUCH FOR PARTICIPATING AND GOOD LUCK!

Figure 1

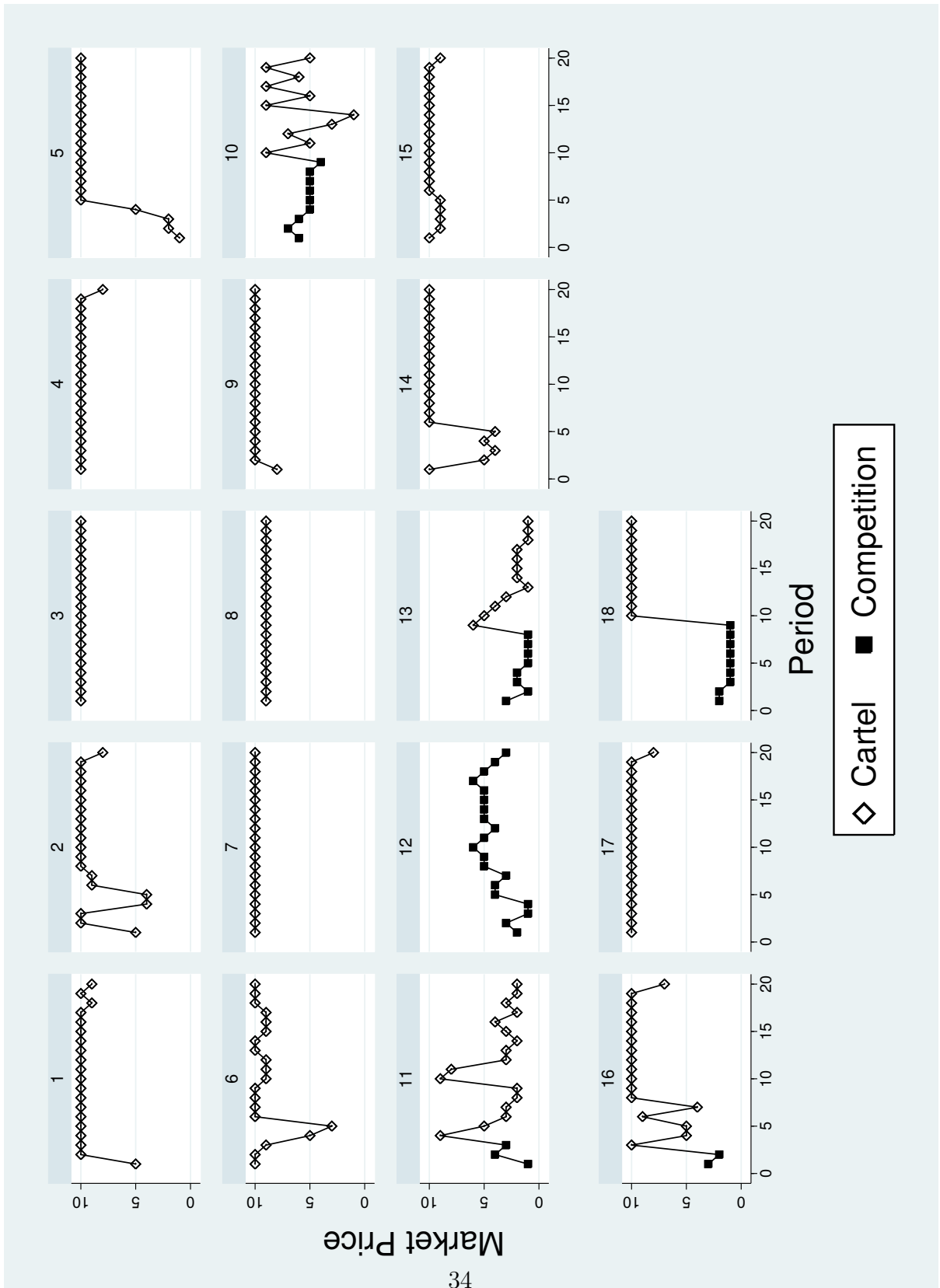Will you lose points in this period?
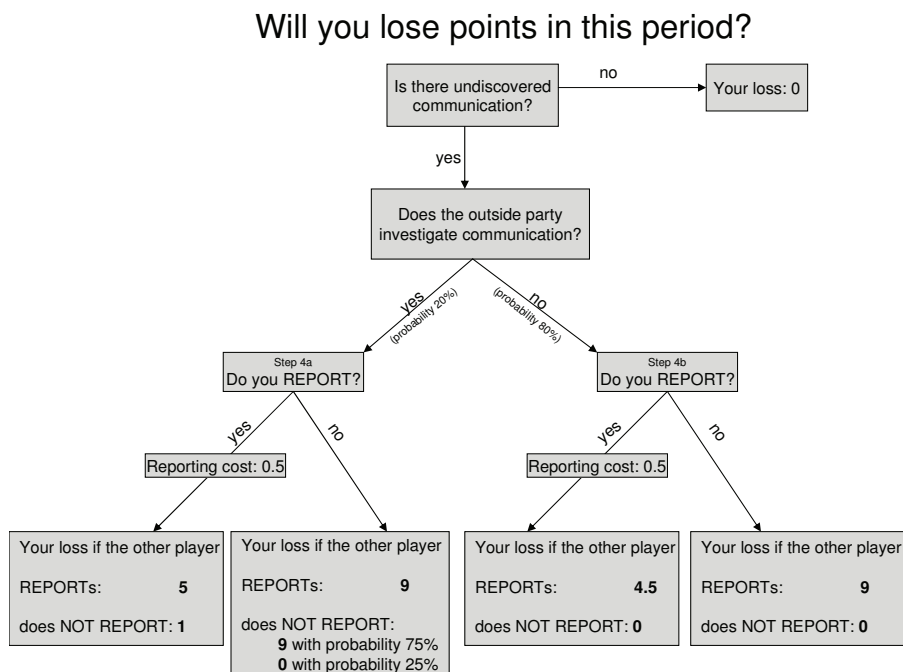
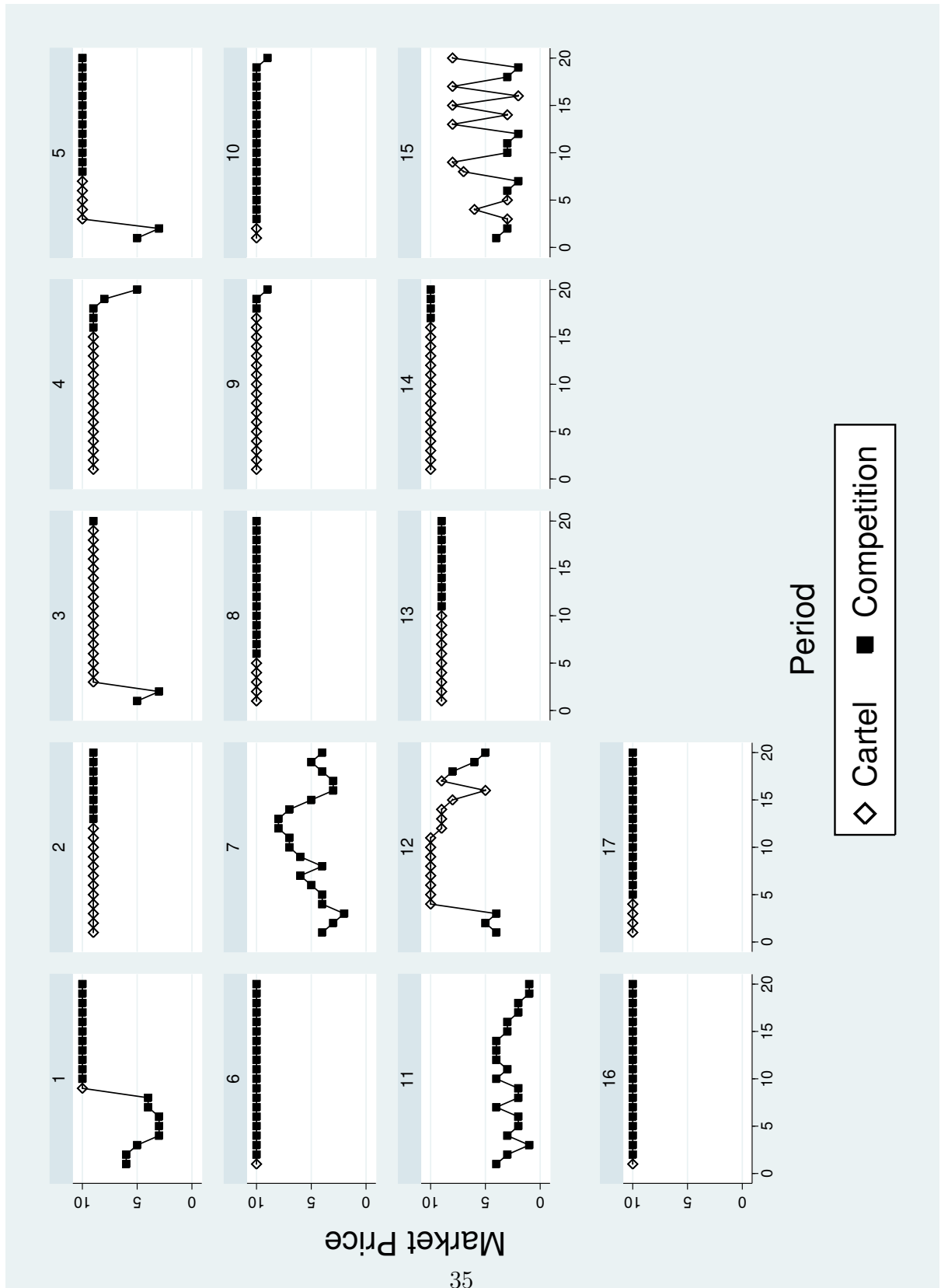Figure A1: Market price in each period per group in Benchmark

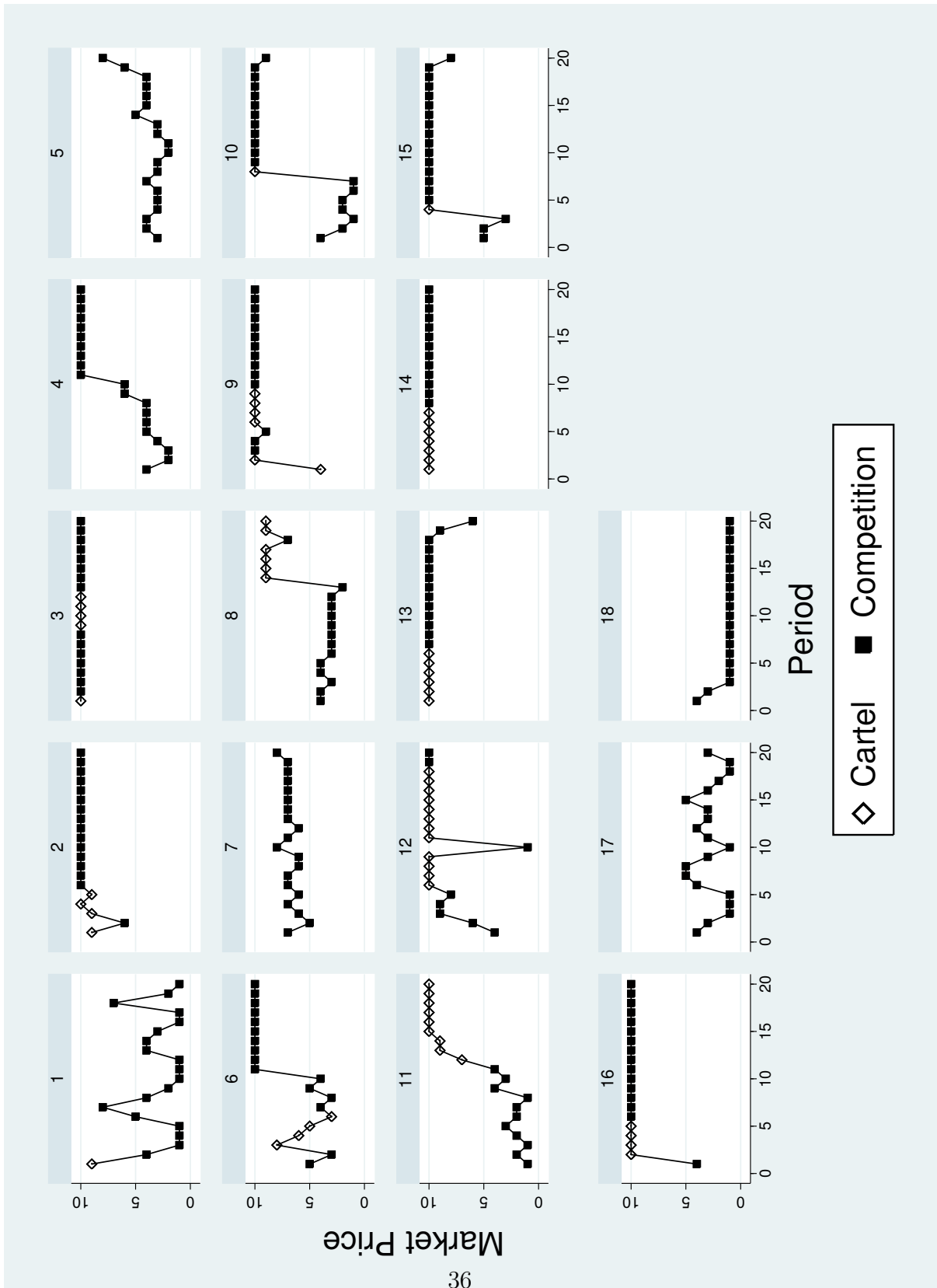Figure A2: Market price in each period per group in Antitrust

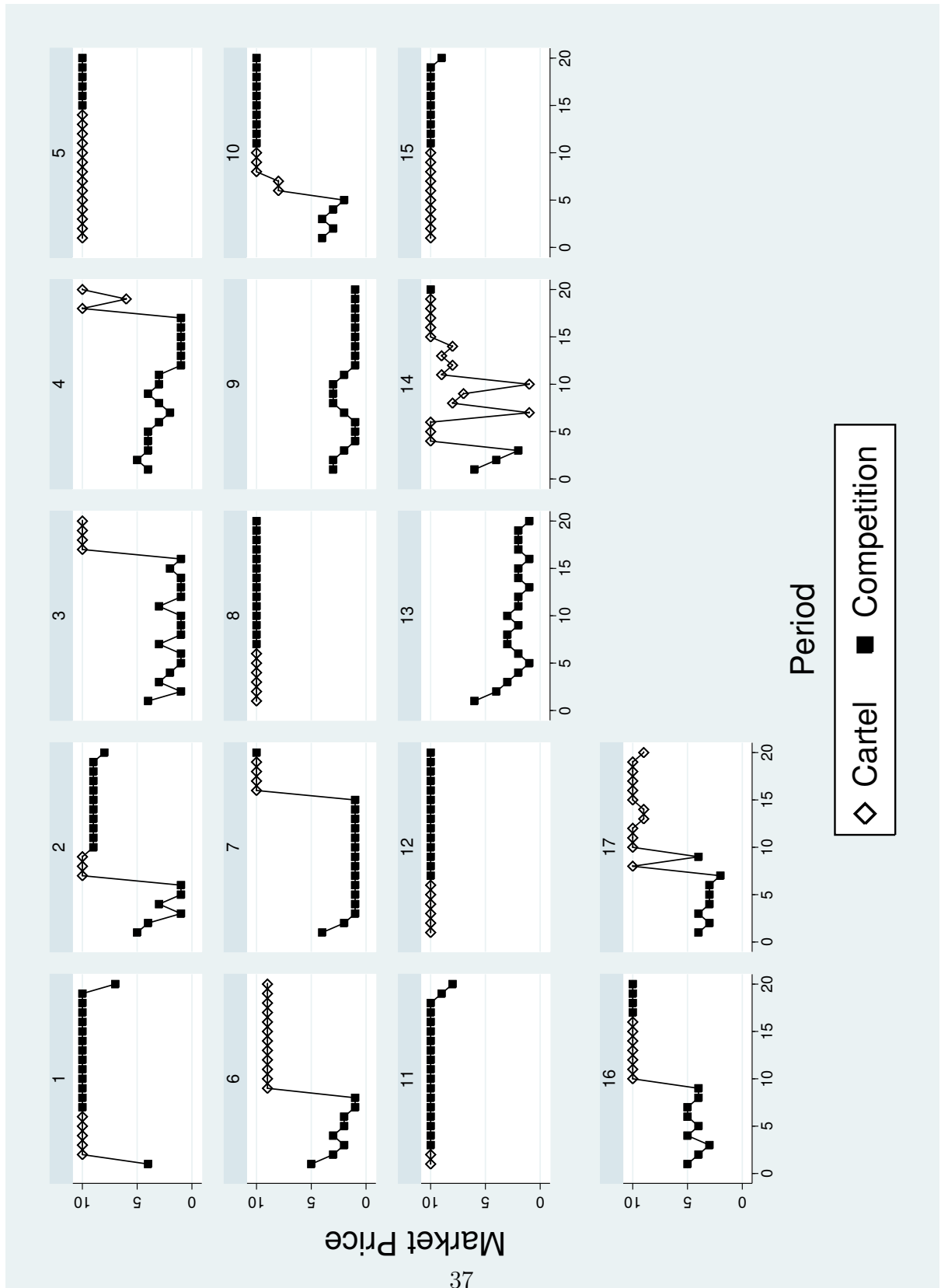Figure A3: Market price in each period per group in Profound

Figure A4: Market price in each period per group in Superficial