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Natalia Pavlova, Andrey Shastitko

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Natalia Pavlova[1], *Andrey Shastitko*[2]

EFFECTS OF HOSTILITY TRADITION IN ANTITRUST: LENIENCY PROGRAMS AND COOPERATION AGREEMENTS[3]

The article focuses on the effects that type I errors can have on the incentives of firms to compete, collude or engage in efficiency promoting socially beneficial cooperation. Our results confirm that in the presence of type I errors the introduction of a leniency program can have ambiguous effects, including the destruction and prevention of welfare enhancing horizontal cooperation agreements. The obtained results help understand the negative impact the hostility tradition resulting in type I enforcement errors can have on social welfare when applied to the regulation of horizontal agreements.

JEL-codes: D43, K21, L41

Key words: antitrust, competition, collusion, cooperation agreements, leniency, enforcement errors.

[1] National Research University Higher School of Economics, Institute for Industrial and Market Studies, Laboratory for Antimonopoly and Competition Policy, Researcher; Russian Presidential Academy of National Economy and Public Administration, Center for Competition and Economic Regulation Studies, Senior researcher; Moscow Lomonosov State University, Chair of Competition and Industrial Policy, Deputy head of the Chair; E-mail: nspavlova86@gmail.com

[2] Moscow Lomonosov State University, Chair of Competition and Industrial Policy, Head of the Chair; Russian Presidential Academy of National Economy and Public Administration, Competition and Economic Regulation Research Center, Director; National Research University Higher School of Economics, Institute for Industrial and Market Studies, Senior scientist; E-mail: saedd@mail.ru

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INTRODUCTION

Cartels are considered to be one of the most dangerous types of antitrust violations. The substantial harm they can cause is only one side of the problem. The other is that, as cartels are considered to be an illegal (sometimes criminal) practice, their participants go to lengths to hide the existence of such agreements, making this type of violation one of the most difficult for the antitrust authorities to detect. One of the methods of uncovering information about cartels is active repentance in the form of leniency programs for cartel participants.

As leniency programs (LP) are implemented in more and more countries, we find evidence of both its successes and its failures[4]. Researchers so far have pointed out many possible ambiguous effects the program can have on firms' incentives. One of the topics that so far has not been sufficiently studied is the effect of type I errors on deterrence with the presence of LPs. This is supported by a recent study by Yusupova (2013), who found that in the Russian case a lot of agreements that were uncovered with the help of leniency were not hard-core cartels, but other types of agreements, including those that can hardly be considered as restricting competition.

The aim of this paper is twofold. First, we analyze how an LP could have affected the incentives of firms that took part in socially beneficial cooperation, considering that such a program gave them a potential way of escaping liability erroneously imposed on parties to horizontal cooperation agreements that were mistakenly qualified as cartels. It seems that such firms could have made false claims for leniency to guarantee that they paid no fines, whereas if the agreements were analyzed in more detail with a wider set of economic tools, they would have been found beneficial to social welfare. Second, we analyze whether the affected incentives could explain why the LPs in Russia resulted in such a structure of uncovered cases, where the main part of the array is not comprised of hard-core cartels.

In order to answer these questions, we extend the models of Motta and Polo (2003) and Ghebrihiwet and Motchenkova (2010) to include the probability of both type I and type II errors committed by an antitrust agency, and three alternative strategies for the firms: colluding, competing, and entering "cooperation" agreements. The underlying logic is that if the antitrust agency considers evidence of efficiency-promoting cooperation agreements as proof of collusion, the gains from cooperation decrease. If gains from cooperation are low enough, producers give up efficiency-promoting cooperation agreements in equilibrium.

[4]For some recent Russian examples see Avdasheva, Shastitko (2011), Pavlova (2012) and Yusupova (2013).

The paper is organized as follows. Section1givesabriefsummary of the relevant literature. Section 2 introduces our main assumptions, the model and the equilibria. Section3describes the main results. Section 4 concludes.

1 LITERATURE REVIEW

There are multiple lines of literature with a direct bearing on our model. The first one is the literature on LPs. We shall build upon the models of Motta and Polo (1999, 2003), which show how implementing an LP can lead to contradictory effects and ambiguous results. Spagnolo (2004) demonstrates the important role of rewards to whistle-blowers for the efficiency of LPs. Harrington (2008) clearly marks out some of the ambiguous effects of the program (the “race to the courthouse”, “cartel amnesty” and “deviator amnesty” effects) and shows which forms of the program can encourage the prevalence of wanted effects. Aubert, Rey, Kovacic (2006) take into account not only corporate LPs, but also individual leniency and more specifically, individual rewards for whistle-blowing. They demonstrate the important effect individual leniency can have on destabilizing cartels, but also pointing out its potential spill-over effects. Most of the other, more recent works build upon these models, expanding them to predict the different possible effects of the chosen forms of LPs. Motchenkova, Leliefeld (2010) capture the effect of industry asymmetry, Motchenkova, van der Laan (2011) – the asymmetry of firms.Herre, Rasch (2009) and Bos, Wandschneider (2012) tackle the problem of leniency for cartel ring-leaders. Roux, von Ungern-Sternberg (2007), Dijkstra, Schoonbeek (2010), Lefouili, Roux (2012), Marshall, Marx, Mezzetti (2013) deal with the effects of leniency in multi-market settings.Houba, Motchenkova, Wen (2009) and Chen, Rey (2012), among other aspects, consider optimal amnesty for repeat violators.

If most of the above listed works incorporate the assumption that the antitrust authority can make type II errors, mistakenly allowing violators to “walk free”, almost none of them take into account the non-zero probability of type I errors, when the authority mistakenly fines innocent firms. An exception is Aubert, Rey, Kovacic (2006), where the authors establish that the size of individual rewards should be limited in order not to trigger false claims from firms engaging in socially optimal cooperation. A more thorough study of the effects of type I errors can be found in Ghebrihiwet, Motchenkova (2010). Our own model will rely heavily on the latter and the similarities and differences between their model and ours will be expanded upon in the next section.

This asymmetry in the study of effects of two types of errors seems unusual since the interplay of type I and II errors and their effect on deterrence and socially beneficial cooperation is a topic actively debated in literature on antitrust economics and law and economics. This includes such works as Posner (1998), Joskow (2002), Manne and Wright (2009), Rill and Dillickrath (2009), Rizolli and Saraceno (2011), Garoupa and Rizolli (2012), Immordino and Polo (2013), Shastitko (2011).

Negative effects of type I errors in deterring cartels would not have been as critical if not for the fact that so many forms of cooperation between competitors might be socially beneficial. The nature of these “non-standard” contracts, which can (and did) arouse suspicion from researchers and regulators as potentially harmful to competition, is closely studied (albeit mostly in terms of vertical contracts) in transaction cost theory (Williamson (1985; 1996), Menard (2004)). The term “hostility tradition” was introduced by Williamson to describe the situation when any economic practice deviating from a simplified standard is considered to be evidence of market power. This idea might be found also in the paper by Coase (1972) devoted to the development of industrial organization theory. In spite of clearly stating the problem of the origins of the hostility tradition, researchers have so far been unable to show just how such a tradition can manifest itself and what sort of consequences it can lead to if cartels and socially beneficial cooperation between competitors are not sufficiently demarcated.

2 THE MODEL

2.1 Assumptions

The model is an extension of the model developed by Ghebrihiwet and Motchenkova (2010), which itself builds upon the model by Motta and Polo (2003). Ghebrihiwet and Motchenkova attempt to fill the void in the study of type I errors and leniency by adding the probability of type I errors to the model of Motta and Polo. They derive some interesting results, e.g. that innocent firms may use plea bargaining as insurance against a type I error, but at the same time this model does not allow us to analyze self-reporting of cooperating firms. We extend the model of Ghebrihiwet and Motchenkova (2010) to take into account the effects of LPs on horizontal cooperation of the kind that is beneficial to social welfare. Additionally, their model does not allow innocent firms to apply for leniency, but instead gives them the opportunity to plead guilty in a pre-trial settlement. The main reason given for this is that in exchange for leniency the firm must provide evidence of collusion, while an innocent firm can provide none. We assume that firms can enter into agreements that are not aimed at harming competition, but can be interpreted as such by an authority that can make errors. In this case, innocent firms - in exchange for leniency - *can* provide the sort of information that can be used to "prove" the fact of collusion.

Finally, in Ghebrihiwet and Motchenkova(2010) the probabilities of type I and type II errors are the same across all possible behavioral strategies. We propose to take into account that antimonopoly authorities have some experience allowing it to distinguish different types of behavior on a market. That way the probability for a colluding firm to be found guilty is higher than for a firm that does not in fact violate the law. This point reflects some particularities of administrative procedures taken into account by antitrust authorities to initialize the case and to make decisions based on evidence collected and interpreted.

Following Motta and Polo (2003), and Ghebrihiwet and Motchenkova (2010), we analyze a group of perfectly symmetric firms. The firms choose between competing, colluding, deviating from the collusive strategy and cooperating (the corresponding profits are Π_N, Π_M, Π_D and Π_{COOP}). Since all firms are symmetric, they all choose the same strategy in equilibrium. The antitrust authority chooses an enforcement policy which can include the use of a leniency program. Firms take into account the policy of the antitrust authority. The collusive agreement prescribes both the market behavior and the behavior towards the antitrust authority: whether the firm reveals information about the cartel if monitored.

At period $t = 0$ the antitrust authority sets the policy parameters: the full fine F ($F > 0$), the reduced fine $R(0 < R < F)$ and the probabilities of firms being investigated and prosecuted. To clarify our assumptions we suggest some comments. Here we interpret the fine in the economic sense, assuming that any form of punishment for an antitrust violation can be monetized and therefore expressed in terms of a monetary fine. Alternatively, the potential punishment (F) can be interpreted as a composite figure that can include an administrative or criminal fine (F_f), a prison sentence (F_p) and civil damage claims (F_d) (this corresponds to the Russian system of sanctions for antitrust violations, and the following discussion applies to the situation in Russia):

$$F = F_f + p_p F_p + p_d F_d.$$

Here we denote the probabilities of a prison sentence and of damage claims as p_p and p_d, probabilities that might be sufficiently lower than 1. The reasoning behind this is that due to some institutional factors such probabilities may be much smaller than 1: for example, if fines and prison sentences are administrated by different authorities, a violator receiving a fine does not receive a guarantee that another authority will find enough proof of him deserving a prison sentence. Similarly, even though civil damages can be theoretically possible, given the fact that cartel damages are frequently distributed among many firms in relatively small amounts, and given the free-rider problem, the probability of civil damage claims may also be de facto close to zero. This way, the fact that the model explicitly deals with only fines and not other types of potential sanctions may also reflect the fact that the probabilities of these sanctions are very small.

We extend Ghebrihiwet and Motchenkova (2010) by assuming that the probabilities of an investigation opening and ending in a conviction are different across different market strategies. We denote the probability of the antitrust authority starting an investigation against a firm that neither colludes nor cooperates by α_0, and the probability of that investigation ending in a conviction by p_0. For colluding firms the probabilities are α_1 and p_1; for firms deviating from a cartel agreement - α_2 and p_2; for cooperating firms - α_3 and p_3. All the probabilities fall between 0 and 1, and $\alpha_0 \neq \alpha_1 \neq \alpha_2 \neq \alpha_3, p_0 \neq p_1 \neq p_2 \neq p_3$.[5]

The timing of the game is as follows. The antitrust authority monitors the behavior of firms in the market. An investigation, once opened, can last one or two periods. In the first phase an investigation is started with a certain probability. If a firm confesses, the authority ends the investigation, and finds a violation with probability 1. The firm that confessed receives a reduced fine and is made to compete in the current period. If no firm confesses, the investigation continues for a second period and ends in a conviction with a probability that is less than 1. If found guilty, the firm is made to pay the full fine and compete in the second period. We assume that any firm that admits to a cartel is granted a reduced fine, independent of whether it was the first to do so. Consequently, the game restarts. We assume infinite repeat. Our model is based on games without memory, so once the game restarts after one or two periods it is of no consequence whether a firm has been previously convicted. Therefore, another assumption we use here is that recidivism is not a reason for increasing the severity of the punishment. This might not always be the case with existing fine systems, where recidivism is widely considered to be an aggravating circumstance. A way of making the model more realistic in this aspect is to switch to games with memory, but this lies outside the scope of our current analysis. Consequently, in our model we will assume a forgiving antitrust authority that does not increase punishment if a firm makes repeated violations.

We now take a closer look at the firms' strategies and their corresponding values.

2.2 Values of strategies

[5] We mention here that, for an antitrust authority, increasing the probability α can possibly lead to a decline in p and vice versa due to the limited nature of the authority's resources. On the other hand, this might not be the case if, for example, the antitrust authority adopts new techniques or instruments, increasing the quality of analysis – that way both the probabilities can change in the same direction.

1. Not Collude or Cooperate(N)

By choosing this strategy, each firm receives profits Π_N in each period. In the first period the antitrust authority starts an investigation with probability α_0. In the second period with probability p_0 the antitrust authority mistakenly finds an infringement and makes the firm pay the full fine *F*. Since the firms in fact compete, they will not be able to provide evidence of collusion in exchange for leniency.

2. Collude and Not Reveal (CNR)

By colluding firms receive Π_M.

In the first period the antitrust authority starts an investigation with probability α_1. Since the firm does not confess, the investigation continues into the second period, in which the antitrust authority makes the firm pay the full fine with probability p_1, while forcing it to compete for one period, or mistakenly lets the firm go without a fine with probability $(1 - p_1)$.

3. Collude and Reveal (CR)

Again, here the firm receives profit Π_M by colluding with other firms on the market.

If the antitrust authority starts an investigation (and this happens with probability α_1), then the firm self-reports in the first period, providing evidence to the antitrust authority. The investigation does not continue into the second period, the firm is found guilty and pays the reduced fine.

4. Deviate and Not Reveal (DNR)

In this case, the firm prefers to take part in a collusive agreement and afterwards to deviate from it. If the other competitors (and counterparts to the agreement) continue to abide by the agreement, it will allow the deviating firm to increase its market share and receive a higher profit - $\Pi_D(\Pi_D > \Pi_M)$ – for one period. Next period the deviation will be observed by the rivals, and collusion will be terminated.

$\Pi_D$can be interpreted the following way: $\Pi_D = \Pi_N + \Delta^e$, where Δ^e is the expected extra profit that the firm expects to gain from deviating if it manages to be the first deviator. Therefore if the unconditional deviator's profit is Δ, then $\Delta^e = \frac{1}{n}\Delta$, where *n* is the number of participants in the cartel.

The antitrust authority starts investigating this firm's behavior with probability α_2. Since the firm does not confess in period 1, the investigation lasts for two periods. In the second period the firm, having deviated already, receives profitΠ_N. The antitrust authority concludes the investigation, falsely establishing the fact of collusion with probabilityp_2, which results in the full fine *F*.

5. Deviate and Reveal (DR)

As in the previous case, the firm enters into a collusive agreement only to deviate from it in the first period (which results in profit Π_D). What follows is infinite punishment for deviation with competitive profits Π_N.[6]

In the first period the antitrust authority starts an investigation with probability α_2. The firm self-reports and receives the reduced fine R. Since in our model evidence provided by one firm is enough to find an infringement, the investigation does not enter into the second period.

Starting from the second period the firm's profit falls to Π_N, but it has the ability to secure for itself a lower fine by using the leniency program, since it can use the initial agreement (even though it wasn't upheld) as proof of collusion.

We note here that, as in the previous case, if all firms choose to deviate, then nobody gets the deviator's profit Π_D and the market outcome is the same as if the firms initially competed.

6. Cooperate and Not Reveal (COOPNR)

By choosing this strategy the firm decides to cooperate (without harm to consumers) with other market participants and earns the cooperative profit Π_{COOP}. We assume that cooperation – as a result of combining resources, optimizing costs, etc. – yields higher profits higher than competitive profits, but lower than collusive (monopoly) profits, so $\Pi_{COOP} > \Pi_N$.[7]

A different question is how the cooperative profit relates to the collusive profit. In theory, any ratio is possible. In an ideal case the cartel profit reaches the level of monopoly profit, and therefore becomes the highest possible profit on the market. Cooperation between firms can lead to an even higher profit, because it leads not to an increase in prices, but to a decrease of costs. Another possibility is that an increase in price will rise to reflect the enhanced quality due to cooperation. Either way, in reality there is no guarantee that the cooperative profit will be higher or lower than the collusive profit.

From the point of view of our model, in the case where $\Pi_{COOP} > \Pi_M$ choosing between colluding and cooperating can lead to only one result: in the latter case not only is the profit higher, but the risk of being fined is simultaneously lower, so the colluding strategy becomes

[6] This might not appear to be a very realistic assumption, provided that with a given market structure firms might find it profitable to return to collusion after a series of punishment periods. A different way of approaching this strategy would be allowing a fixed number of periods for punishment or accommodating the evolutionary stable "tit for tat" strategy (Axelrod, 1984). This extension of the model might be a line for future research.

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dominant. So the case that we will focus upon is when$\Pi_{COOP} < \Pi_M$, and we shall examine it more closely.

The antitrust authority opens an investigation with probabilityα_3. The profit in the first period is Π_{COOP}, and the firm does not collaborate with the authorities, so the investigation takes up one more period. If in the second period the authority falsely finds an infringement (which happens with probability p_3), then the firm pays the full fine F and receives profit Π_N. Otherwise, there is no fine, and the profit is Π_{COOP}. Then the game restarts.

7. Cooperate and Reveal (COOPR)

Here, again, the antitrust authority starts the investigation with probability α_3. But unlike the previous case, the firm makes a false confession, admitting to collusion in exchange for a reduction of fines (even though in reality the agreement did not cause harm to social welfare). The antitrust authority accepts the provided information as proof of collusion and the firm pays the reduced fine. We assume that the confession of a firm automatically leads to the authority finding an infringement. Simultaneously, in the first period the authority forces the firm to behave competitively (the firm's profit equals Π_N), and breaks up the cooperation. The game restarts in the second period.

Is it a valid assumption that, on the one hand, the antitrust authority can distinguish between different types of market behavior (although errors are possible), expressed in our model through the different probabilities of opening the investigation and finding an infringement for different strategies, but at the same time it cannot tell a cooperation agreement apart from a cartel agreement, even after "getting its hands on" the agreement itself? We consider such a scenario to be plausible, judging by the experience of antitrust enforcement in Russia, and also by the possible incentives that define the behavior of the authority's staff. Here we will not be getting too deep into this problem, but we consider that, if we take as a starting point not the "public interest" view, but public choice theory, and if we take into account some political factors – namely, the incentive to show as many cases solved with the help of LPs as possible, in a situation where the fight against cartels is positioned as a high priority and the new LP is expected to yield a visible, tangible result- the antitrust authority may find itself in no position to decline leniency applications on the grounds that the agreement that the applicant admitted to being part of is in fact a legal one. On the other hand, the authority may have some incentive to still analyze the detected agreement and refrain from punishing innocent firms, but in our model we will assume that the confession of a firm automatically leads to the authority finding an infringement.

Similarly to Motta and Polo (2003), values of the above mentioned strategies in parametrical form can be found in Table 1.

Table 1. Values of strategies

Strategy	Value	Value after rearranging
N	$V_N = \alpha_0\{\Pi_N + \delta[p_0(\Pi_N - F) + (1 - p_0)\Pi_N]\} + (1-\alpha_0)(\Pi_N + \delta\Pi_N) + \delta^2 V_N$	$V_N = \frac{\Pi_N}{1-\delta} - \alpha_0 p_0 \frac{\delta F}{1-\delta^2}$
CNR	$V_{CNR} = \alpha_1\{\Pi_M + \delta[p_1(\Pi_N - F) + (1 - p_1)\Pi_M]\} + (1-\alpha_1)(\Pi_M + \delta\Pi_M) + \delta^2 V_{CNR}$	$V_{CNR} = \frac{\Pi_M}{1-\delta} - \alpha_1 p_1 \frac{\delta(\Pi_M - \Pi_N + F)}{1-\delta^2}$
CR	$V_{CR} = \alpha_1(\Pi_N - R) + (1-\alpha_1)\Pi_M + \delta V_{CR}$	$V_{CR} = \frac{\Pi_M}{1-\delta} - \alpha_1 \frac{\Pi_M - \Pi_N + R}{1-\delta}$
DNR	$V_{DNR} = \alpha_2\{\Pi_D + \delta[p_2(\Pi_N - F) + (1 - p_2)\Pi_N]\} + (1-\alpha_2)(\Pi_D + \delta\Pi_N) + \delta^2 V_N$	$V_{DNR} = \Pi_D + \frac{\delta\Pi_N}{1-\delta} - \alpha_2 p_2 \frac{\delta F}{1-\delta^2}$
DR	$V_{DR} = \alpha_2(\Pi_D - R) + (1-\alpha_2)\Pi_D + \delta V_R$, where $V_R = \alpha_2(\Pi_N - R) + (1-\alpha_2)\Pi_N + \delta V_R$	$V_{DR} = \Pi_D + \frac{1}{1-\delta}(\delta\Pi_N - \alpha_2 R)$
COOPNR	$V_{COOPNR} = \alpha_3\{\Pi_{COOP} + \delta[p_3(\Pi_N - F) + (1 - p_3)\Pi_{COOP}]\} + (1-\alpha_3)(1 + \delta)\Pi_{COOP} + \delta^2 V_{COOPNR}$	$V_{COOPNR} = \frac{\Pi_{COOP}}{1-\delta} - \alpha_3 p_3 \frac{\delta(\Pi_{COOP} - \Pi_N + F)}{1-\delta^2}$
COOPR	$V_{COOPR} = \alpha_3(\Pi_N - R) + (1 - \alpha_3)\Pi_{COOP} + \delta V_{COOPR}$	$V_{COOPR} = \frac{\Pi_{COOP}}{1-\delta} - \alpha_3 \frac{\Pi_{COOP} - \Pi_N + R}{1-\delta}$

2.3 Subgame perfect equlibria

To find the subgame perfect equilibria, we compare values of the strategies listed above. Since from the start we assumed symmetry between the firms, it follows that if one firm finds a certain strategy optimal, so do all the other firms.

To simplify the comparison, we make some additional assumptions about probabilities α and p. This can be done in multiple ways, but the key will be the markers that the antitrust authority uses to identify cartel agreements. A study of cartel behavior and the possible effects that can draw the attention of antitrust authorities can be found in Harrington (2006). We will use two characteristics that can be interpreted by the antitrust authorities as markers of cartels: the existence of an agreement between competitors and the existence of profits that are higher than the competitive level. This way itseemslogicaltoassumethatthelowestprobabilitiesare applicable forfirmsthatoriginallycompete – that is, theyneithercollude nor cooperate on the market. Inthiscase, notonlyistherenotraceofanyagreement, thereisalsonoevidenceofexcessiveprofit.By the same logic, the highest probability of investigation and prosecution exists for the case where both a collusive agreement and a collusive profit are present – and this is the case of collusive strategies, so the highest probabilities are α_1 and p_1.

For firms deviating from the agreement we can assume the following. Even though the firm acted competitively in the first period by undercutting its rivals' price, it had still entered the agreement at some previous point in time – otherwise there would be nothing to deviate from. Therefore, some proof of the existence of a cartel agreement exists, even though the profits received by firms do not support the assumption that collusion took place. For these reasons we maintain that the probability of prosecution in this case, p_2, is higher than in the case of competition, but lower than in the case of collusion, $\alpha_0 < \alpha_2 < \alpha_1$, $p_0 < p_2 < p_1$.

For cooperating firms the situation is as follows. Since there is a certain agreement between firms, which is difficult to distinguish from a cartel agreement due to the inclusion of ancillary restraints, and since if the cooperation is successful, firms will receive a profit that is higher than the competitive profit, we assume that the probabilities of prosecution are higher than in the case of competition, but lower than in the case of collusion, $\alpha_0 < \alpha_3 < \alpha_1$, $p_0 < p_3 < p_1$.

A more difficult issue is the correlation between probabilities for deviating firms and cooperating firms. In both cases some sort of agreement between competitors exists that can be detected by the antitrust authorities and interpreted as evidence of collusion. But, in case of deviating, competition can be observed (as a process): behavior on the market shows that firms actively compete by undercutting each others' prices. On the other hand, for the deviating strategy the available evidence that can be used as proof of collusion is only the agreement itself, while for cooperation there is both an agreement and a market outcome that can resemble collusion. Thus, we can assume that a cooperation agreement is more likely to draw attention and end in prosecution than an agreement that has never been executed. Hence, we consider $\alpha_0 < \alpha_2 < \alpha_3 < \alpha_1$, $p_0 < p_2 < p_3 < p_1$[8].

We will try to define the conditions for α and p that influence which strategy becomes dominant. In order to do this, for purposes of simplification and obtaining an illustration to our conclusions, we assume fixed ratios between probabilities α_i and p_i and compare the values of the denoted strategies.

We assume that $\alpha_0 = 0{,}2\alpha; \alpha_1 = \alpha; \alpha_2 = 0{,}4\alpha$; $\alpha_3 = 0{,}6\alpha$ and $p_0 = 0{,}2p$; $p_1 = p; p_2 = 0{,}4p$; $p_3 = 0{,}6p$. These values satisfy the conditions $\alpha_0 < \alpha_2 < \alpha_3 < \alpha_1$, $p_0 < p_2 <$

[8] Of course, other variants are possible. The study of different ratios of probabilities is a topic for future study. More on the relationship of type I and II errors depending on the choice between per se prohibition of practices and the rule of reason can be found in Katsoulakos, Ulph (2009).

$p_3 < p_1$, and seem feasible in light of the meaning of these parameters.We will also assume that the amount of the reduced fine is zero (R=0).

The Appendix contains the relevant calculations.

We find the values of α and p that cause certain strategies to dominate. For our chosen illustrative example (see Appendix) the equilibrium is:

1) CNR - if $0 < p < 0.75$ and $0 < \alpha < \frac{25}{68p}$;

2) CR – if $0.75 < p \leq 1$ and $0 \leq \alpha < \min[\frac{2,5}{7.5-3.2p}; \frac{5}{9}]$;

3) COOPNR – if $\frac{25}{68} < p < \frac{3}{3.2}$ and $\max\left[\frac{25}{68p}; \frac{2,5}{7,5-3,2p}\right] < \alpha < \frac{2}{3,2p}$;

4) COOPR – if $\frac{3}{3.2} < p \leq 1$ and $\frac{5}{9} < \alpha < \frac{2}{3}$;

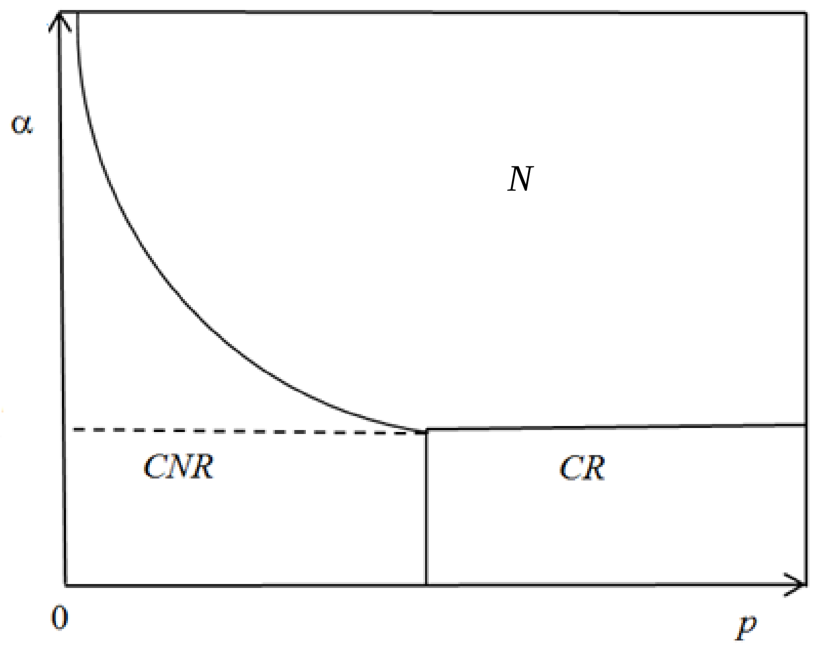
5) N – for all other conditions (as long as all the values of α_i and p_i fall into the segment [0; 1]).

3 RESULTS AND DISCUSSION

3.1 Characterization of subgame perfect equilibria

The model of Motta and Polo (2003), which we used as our benchmark model, resulted in three types of subgame perfect equilibria: CR, CNR and N. They are illustrated in Figure 1.

Figure 1.The results of Motta and Polo (2003)



One of the main findings of Motta and Polo was that even when using a very “generous” version of the program – where the applicant can receive full immunity from fines (R=0)–not all cartels on the market are broken up: there are areas where firms still choose to collude and either reveal or not (CNR and CR). This happens when the probability to start an investigation α is low. If at the same time the probability of successful prosecution (p) is low, then firms do not have incentives to confess, and we end up in the area CNR, where firms collude and do not reveal information about it. On the other hand, if the antitrust authority has sufficient resources and incentive to ensure high probabilities of investigation and prosecution, then cartels are prevented.

For our extended model, we find that the number of possible types of subgame perfect equilibria increases to five:

1) firms collude and do not reveal information about the cartel to antitrust authorities (CNR);

2) firms collude and reveal (CR);

3) firms cooperate and do not confess to colluding (COOPNR);

4) firms cooperate and confess to colluding (COOPR);

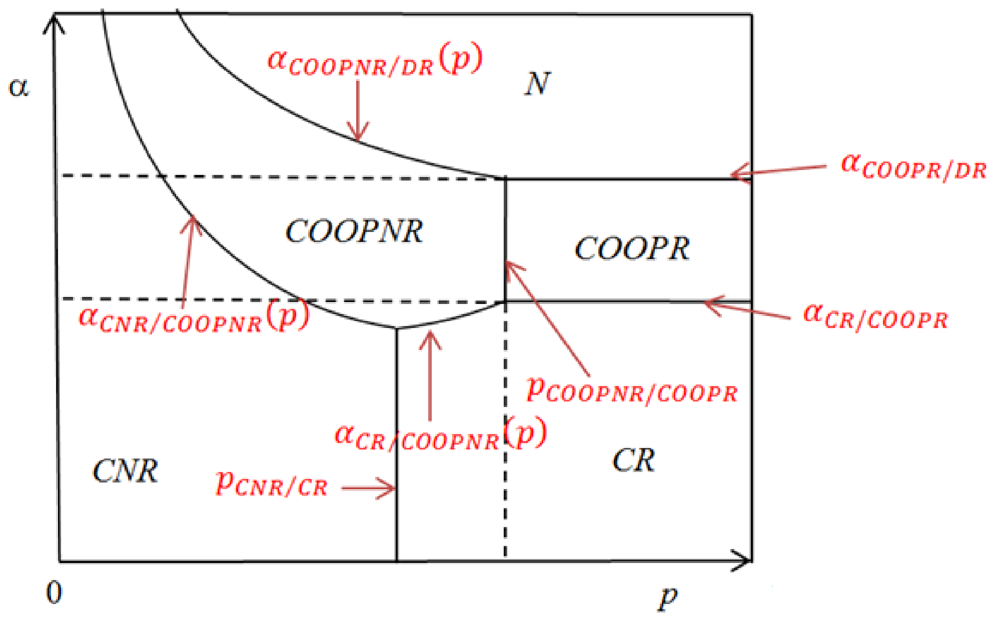
5) no collusion or cooperation occurs (N).[9]

The results are illustratedin Figure2.

The N, COOPNR, COOPR, CNR, and CR areas denote different types of equilibria that depend on the values of $\alpha$and p.$\alpha_{COOPNR/DR}(p)$is a curve above which the firms prefer the strategy DR (resulting in the equilibrium N), and below which the firms prefer COOPNR; thresholds $\alpha_{CNR/COOPNR}(p)$, $\alpha_{CR/COOPNR}(p)$, $\alpha_{COOPR/DR}$ and $\alpha_{CR/COOPR}$ have similar interpretation. The line $p_{CNR/CR}$ defines the border between areas of a CNR-type and a CR-type equilibrium; the line$p_{COOPNR/COOPR}$ – the border between COOPNR and COOPR.

Figure 2. Equilibria of the model in axes (α; p)

[9] In the N area, where no collusion or cooperation occurs, the dominant strategy is DR. It becomes more profitable for the firm to reveal after it has already deviated from the agreement, since this way it not only receives a deviator's profit, but also exempts itself from paying a fine.



Proposition 1. Accounting for the possibility of type I errors and cooperation agreements leads to an increase in the number of types of possible subgame perfect equilibria compared to the benchmark model.

3.2 Impact of type I errors

Before attempting to define the role of leniency programs in these results, we will analyze what effect the additional assumption of type I errors has on market behavior.

Proposition 2. Excluding the possibility of type I errors in the model leads to only three types of equlibria remaining: CNR, CR and COOPNR.

Since the probability of being unfairly fined by the antitrust authority is now zero, the value of strategy COOPNR changes. The value of this strategy is now defined as the following:

$$V_{COOPNR} = \Pi_{COOP} + \delta\Pi_{COOP} + \cdots = \frac{\Pi_{COOP}}{1-\delta}.$$

COOPNR starts to dominate COOPR, DNR, DR and N for the following reasons.

Firstly, since the antitrust authority now no longer confuses cooperation and collusion, there is no incentive to make a false confession and not only incur an undeserved fine, even if it is reduced, but also destroy the existing cooperation for one period. Similarly, DNR starts to dominate DR.

Secondly, since the antitrust authority does not make type I errors, cooperation becomes a better strategy than competition for any given values of parameters of α and p[10] (if $\Pi_{COOP} >$

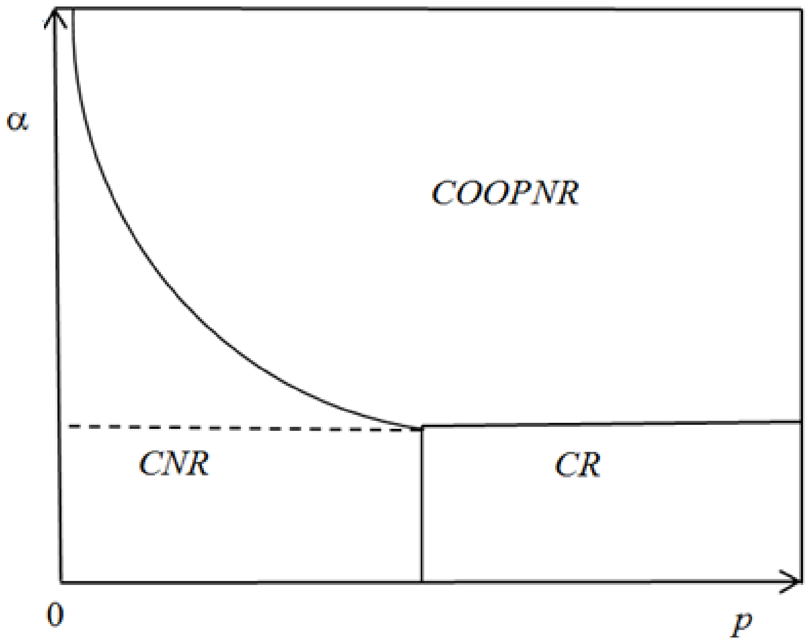
[10] In our model we assume that cooperation is an available strategy to all firms, which is not always the case in reality.

Π_N holds). It follows that if a firm has the ability to take part in a cooperation agreement, it will always be profitable for it to do so.

Thirdly, the ratio of the values of strategies COOPNR and DNR stops being dependent upon α and$p$ and is now defined by the ratio of the corresponding profits. In our example the ratio of the profits ensures that COOPNR becomes the dominating strategy.

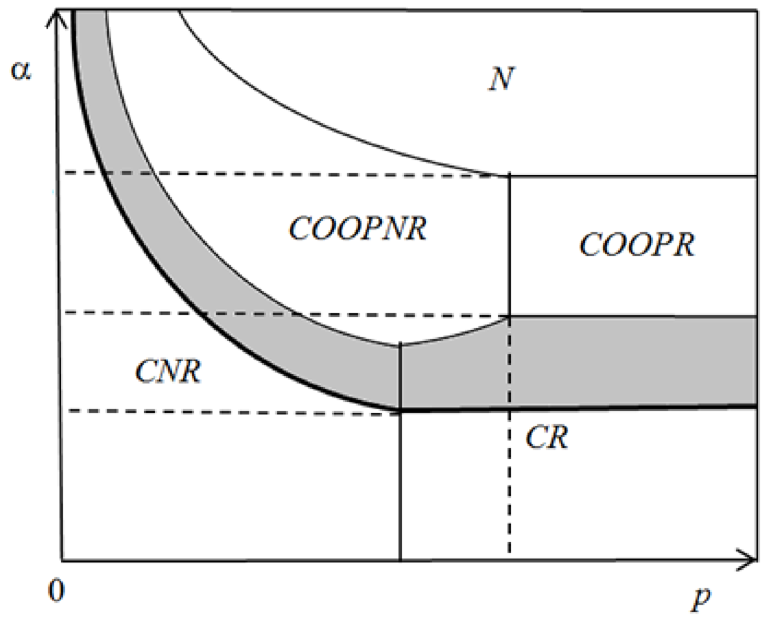
By comparing values of strategies and using the same parameters as previously, we derive that an analogue of the model of Motta and Polo (2003) in our example would lead to the results illustrated in Figure 3.

Figure 3.The results of Motta and Polo (2003) with cooperation



Finally, we illustrate the comparison of results derived with and without the assumption of type I errors (Figure4).

Figure 4. Impact of type I errors on the effectiveness of leniency programs



The grey areas are those where in the absence of type I errors firms used to cooperate (and not make false claims for leniency) in equilibrium – but after taking into consideration type I errors we find that these are areas where collusion appears. And not all of the grey area is where firms confess after colluding: if *p* is low enough, firms collude without confessing.

This result corresponds with the results of Ghebrihiwet and Motchenkova (2010): by taking into account type I errors we see that for certain policy parameters firms that in fact never caused damage to social welfare change their behavior and start taking actions that do cause damage. Expecting that even competitive behavior can be prosecuted, firms find it best to start "deserving" their punishment – that way they at least compensate by receiving collusive profits.

An effect that was not studied by Ghebrihiwet and Motchenkova (2010), and which has not yet been the object of systemic analysis in the context of leniency programs, is the impact on "conscientious" cooperation. Our model shows that in areas where socially beneficial cooperation was possible in equilibrium in the absence of type I errors, "switching on" such errors leads to the appearance of areas where cooperation either never arises (N), or does arise only to be terminated if it draws the attention of the antitrust authority (COOPR).

The two latter effects correspond to the findings of Shavell and Polinsky (1989), who argued that an increase in the probability of type I errors can lead to economic agents becoming more inclined towards violating rules, and at the same time to the results of Png (1986), who concluded that an increase in the probability of type I errors can lead to an even higher level of compliance. In their own way our results seem to reconcile these two seemingly contradictory findings: we see that in our model these effects are not mutually exclusive, but the prevalence of one or the other depends on deterrence parameters $\alpha$and$p$.

This leads us to formulate Proposition 3.

Proposition 3. The presence of type I errors results in collusion becoming sustainable for a wider set of parameter values and has a detrimental impact on socially beneficial cooperation.

3.3 Effect of leniency on the incentives to cooperate

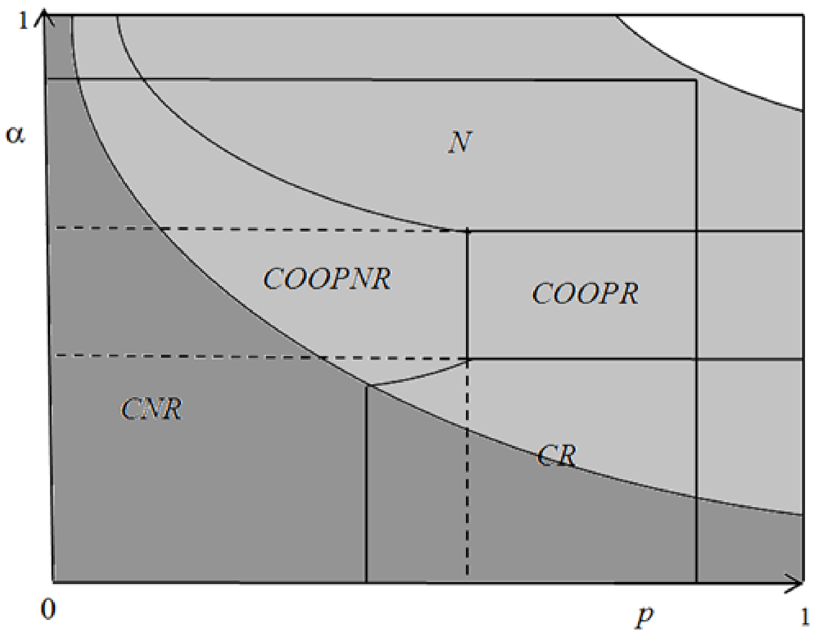
To analyze the effect of leniency on incentives to cooperate in the presence of type I and II errors we will first look at the case where a confession does not get rewarded by a reduction of fines.

In this case CNR, DNR and COOPNR become dominant strategies over CR, DR and COOPR, which is intuitively clear. Additionally, chosen parameters ensure that DNR dominates N.

This way three types of equilibria are possible: where all firms collude and do not reveal; where all firms cooperate and do not reveal; where firms compete.

The results are illustrated in Figure 5.

Figure 5. Results of the model with and without leniency



The labeled areas correspond with the equilibria in our main model, with leniency. The dark-grey area is where in the absence of leniency the equilibrium CNR exists; in the light-grey area the equilibrium in the absence of leniency is COOPNR. The N equilibrium (white area), where the dominant strategy is DNR, is also possible.

The attained results make it possible to derive some information about the effect of leniency programs when the antitrust authority can make both type I and type II errors.

Firstly, we confirm one of the result obtained by Motta and Polo (2003). With the inclusion of leniency the area where collusion is (in principle) maintainable becomes larger (transition from the dark-grey area to CNR+CR). But the participants of the newly formed cartels prefer to collude and confess; also, some cartels that previously would not have been voluntarily revealed to the authorities are now discovered thanks to confessions exchanged for leniency (dark-grey part of CR).

It is worth mentioning that in our model the “donor”-area for collusion is the locus where in the absence of leniency cooperation was feasible.

One of the most interesting results is that in the appearance of leniency programs in a part of the area where firms used to cooperate they now make false confessions and apply for leniency in order to insure themselves against possible unfair punishment (locus COOPR). This means that in case an investigation starts, the cooperation breaks up. Since we assume the cooperation to be socially beneficial, its destruction due to false self-reporting has a negative impact on social welfare.

Another effect is the dramatic decrease of the area where cooperation is at all maintainable. Previously, with our chosen parameters and without leniency, all the firms that did not collude preferred to cooperate, if given the possibility. But after introducing leniency the area where COOPNR and even COOPR are feasible decreased noticeably, while the area where no cooperation arises increased in size.

The effects described above are summarized in Proposition 4.

Proposition 4. Leniency in the presence of type I errors can lead to the destruction of welfare enhancing cooperation that exists on the market and can also depress incentives to enter into new cooperation agreements.

CONCLUSION

We have shown that the inclusion of type I errors and the extension of the study of collusion to cooperation agreements that benefit social welfare allow us to infer the existence of additional externalities for firms resulting from the introduction of LPs. There are three such main effects (the first two correspond to the findings of Ghebrihiwet and Motchenkova (2010), but are extensions with the addition of possible cooperation agreements):

1) the deserved punishment effect – firms have an incentive to switch from competition or socially beneficial cooperation to collusion so as to guarantee that the punishment they can possibly receive will be deserved. In Figure 5, this is the intersection of the light-grey area and area CR;

2) the disrupted cooperation effect – the result of cooperation agreements becoming destabilized due to the incentive for firms to make false confessions in order to avoid undeserved punishment. This effect is illustrated by the are COOPR, where in the absence of a leniency program cooperation is upheld;

3) the prevented cooperation effect – this effect appears due to the fact that any kind of agreement with a competitor, even if such an agreement is ultimately beneficial to social welfare, can draw the attention of the antitrust authority and increase the possibility of being punished. Consequently firms start to prefer not to engage in any sort of agreements with competitors (the light-grey area N in Figure 5) – a factor that impedes technological progress and innovation and hinders the inflow of investment.

The described effects explain how the hostility tradition in antitrust, by increasing the chance of any form of cooperation being qualified as anticompetitive and therefore illegal, results not only in the destruction of welfare enhancing practices, but also reinforces the stability of cartels.

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APPENDIX

In order to find the subgame perfect equilibria, we need to find the conditions for α and p that make each of the strategies dominant.

To simplify our calculations, we will adopt certain fixed ratios for our probabilities α_i and p_i $(i = 0,1,2,3)$ that satisfy the conditions $\alpha_0 < \alpha_2 < \alpha_3 < \alpha_1$, $p_0 < p_2 < p_3 < p_1$, where $\alpha_i \in [0,1]$, $p_i \in [0,1]$. Let $\alpha_1 = \alpha$ and $p_1 = p$, while $\alpha \in [0,1]$, $p \in [0,1]$. We will now assume that $\alpha_0 = 0.2\alpha$, $\alpha_2 = 0.4\alpha$, $\alpha_3 = 0.6\alpha$ and $p_0 = 0.2p$, $p_2 = 0.4p$, $p_3 = 0.6p$.

We proceed to find the conditions for α and p that ensure each strategy's dominance. In order to do that, we compare the values of all the strategies, substituting for their expressions which we established in section 2 of the paper and simplifying the inequalities. We derive the following results.

1. Conditions for "Nor Collude or Cooperate" being dominant:

$$\begin{cases} V_N > V_{CNR} \\ V_N > V_{CR} \\ V_N > V_{DNR} \\ V_N > V_{DR} \\ V_N > V_{COOPNR} \\ V_N > V_{COOPR} \end{cases} => \begin{cases} \alpha > \frac{(\Pi_M - \Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0.96F)} \\ \alpha > \frac{(\Pi_M - \Pi_N)(1+\partial)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0.04p\delta F} \\ \alpha > \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0.12p\delta F} \\ \alpha > \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0.4R(1+\delta) - 0.04p\delta F} \\ \alpha > \frac{(\Pi_{COOP} - \Pi_N)(1+\delta)}{p\delta[0.36\Pi_{COOP} - 0.36\Pi_N + 0.32F]} \\ \alpha > \frac{(\Pi_{COOP} - \Pi_N)(1+\delta)}{0.6(\Pi_{COOP} - \Pi_N + R)(1+\delta) - 0.04p\delta F} \end{cases}$$

2. Conditions for "Collude and Not Reveal" being dominant:

$$\begin{cases} V_{CNR} > V_N \\ V_{CNR} > V_{CR} \\ V_{CNR} > V_{DNR} \\ V_{CNR} > V_{DR} \\ V_{CNR} > V_{COOPNR} \\ V_{CNR} > V_{COOPR} \end{cases} => \begin{cases} \alpha < \frac{(\Pi_M - \Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0.96F)} \\ p < \frac{(\Pi_M - \Pi_N + R)(1+\delta)}{\delta(\Pi_M - \Pi_N + F)} \\ \alpha < \frac{(\Pi_M - (1-\delta)\Pi_D - \partial\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0.84F)} \\ \alpha < \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + F) - 0.4R(1+\delta)} \\ \alpha < \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{p\delta(\Pi_M - 0.64\Pi_N + 0.64F - 0.36\Pi_{COOP})} \\ \alpha < \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{p\delta(\Pi_M - \Pi_N + F) - 0.6(\Pi_{COOP} - \Pi_N + R)(1+\delta)} \end{cases}$$

3. Conditions for "Collude and Reveal" being dominant:

$$\begin{cases} V_{CR} > V_N \\ V_{CR} > V_{CNR} \\ V_{CR} > V_{DNR} \\ V_{CR} > V_{DR} \\ V_{CR} > V_{COOPNR} \\ V_{CR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_M - \Pi_N)(1+\partial)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0.04p\delta F} \\ p > \frac{(\Pi_M - \Pi_N + R)(1+\delta)}{\delta(\Pi_M - \Pi_N + F)} \\ \alpha < \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0.16p\delta F} \\ \alpha < \frac{\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N}{\Pi_M - \Pi_N + 0.6R} \\ \alpha < \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0.36p\delta(\Pi_{COOP} - \Pi_N + F)} \\ \alpha < \frac{\Pi_M - \Pi_{COOP}}{\Pi_M - 0.6\Pi_{COOP} - 0.4\Pi_N + 0.4R} \end{cases}$$

4. Conditions for “Deviate and Not Reveal” being dominant:

$$\begin{cases} V_{DNR} > V_N \\ V_{DNR} > V_{CNR} \\ V_{DNR} > V_{CR} \\ V_{DNR} > V_{DR} \\ V_{DNR} > V_{COOPNR} \\ V_{DNR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0.12p\delta F} \\ \alpha > \frac{(\Pi_M - (1-\delta)\Pi_D - \partial\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0.84F)} \\ \alpha > \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0.16p\delta F} \\ p < \frac{R(1+\delta)}{0.4\delta F} \\ \alpha > \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta[0.36\Pi_{COOP} - 0.36\Pi_N + 0.2F]} \\ \alpha > \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{0.6(\Pi_{COOP} - \Pi_N + R)(1+\delta) - 0.16p\delta F} \end{cases}$$

5. Conditions for “Deviate and Reveal” being dominant:

$$\begin{cases} V_{DR} > V_N \\ V_{DR} > V_{CNR} \\ V_{DR} > V_{CR} \\ V_{DR} > V_{DNR} \\ V_{DR} > V_{COOPNR} \\ V_{DR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0.4R(1+\delta) - 0.04p\delta F} \\ \alpha > \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + F) - 0.4R(1+\delta)} \\ \alpha > \frac{\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N}{\Pi_M - \Pi_N + 0.6R} \\ p > \frac{R(1+\delta)}{0.4\delta F} \\ \alpha > \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{0.36p\delta(\Pi_{COOP} - \Pi_N + F) - 0.4R(1+\delta)} \\ \alpha > \frac{\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N}{0.6\Pi_{COOP} - 0.6\Pi_N + 0.2R} \end{cases}$$

6. Conditions for "Cooperate and Not Reveal" being dominant:

$$\begin{cases} V_{COOPNR} > V_N \\ V_{COOPNR} > V_{CNR} \\ V_{COOPNR} > V_{CR} \\ V_{COOPNR} > V_{DNR} \\ V_{COOPNR} > V_{DR} \\ V_{COOPNR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_{COOP}-\Pi_N)(1+\delta)}{p\delta[0.36\Pi_{COOP}-0.36\Pi_N+..32F]} \\ \alpha > \frac{(\Pi_M-\Pi_{COOP})(1+\delta)}{p\delta(\Pi_M-0.64\Pi_N+0.64F-0.36\Pi_{COOP})} \\ \alpha > \frac{(\Pi_M-\Pi_{COOP})(1+\delta)}{p\delta(\Pi_M-0.64\Pi_N+0.64F-0.36\Pi_{COOP})} \\ \alpha < \frac{(\Pi_{COOP}-(1-\delta)\Pi_D-\delta\Pi_N)(1+\delta)}{p\delta[0.36\Pi_{COOP}-0.36\Pi_N+0.2F]} \\ \alpha < \frac{(\Pi_{COOP}-(1-\delta)\Pi_D-\delta\Pi_N)(1+\delta)}{0.36p\delta(\Pi_{COOP}-\Pi_N+F)-0.4R(1+\delta)} \\ p < \frac{(\Pi_{COOP}-\Pi_N+R)(1+\delta)}{0.6\delta(\Pi_{COOP}-\Pi_N+F)} \end{cases}$$

7. Conditions for "Cooperate and Reveal" being dominant:

$$\begin{cases} V_{COOPR} > V_N \\ V_{COOPR} > V_{CNR} \\ V_{COOPR} > V_{CR} \\ V_{COOPR} > V_{DNR} \\ V_{COOPR} > V_{DR} \\ V_{COOPR} > V_{COOPNR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_{COOP}-\Pi_N)(1+\delta)}{0.6(\Pi_{COOP}-\Pi_N+R)(1+\delta)-0.04p\delta F} \\ \alpha > \frac{(\Pi_M-\Pi_{COOP})(1+\delta)}{p\delta(\Pi_M-\Pi_N+F)-0.6(\Pi_{COOP}-\Pi_N+R)(1+\delta)} \\ \alpha > \frac{\Pi_M-\Pi_{COOP}}{\Pi_M-0.6\Pi_{COOP}-0.4\Pi_N+0.4R} \\ \alpha < \frac{(\Pi_{COOP}-(1-\delta)\Pi_D-\delta\Pi_N)(1+\delta)}{0.6(\Pi_{COOP}-\Pi_N+R)(1+\delta)-0.16p\delta F} \\ \alpha < \frac{\Pi_{COOP}-(1-\delta)\Pi_D-\delta\Pi_N}{0.6\Pi_{COOP}-0.6\Pi_N+0.2R} \\ p > \frac{(\Pi_{COOP}-\Pi_N+R)(1+\delta)}{0.6\delta(\Pi_{COOP}-\Pi_N+F)} \end{cases}$$

The probabilities must still satisfy $\alpha \in [0,1]$, $p \in [0,1]$.

Depending on specific values of profits, fines and discounting factor, different inequalities in the system will become binding. We will analyze one of the possible combinations of parameters to illustrate some of the effects.

For simplicity, we will assume that $\Pi_N = 0$, $\Pi_M = 1.5$, $\Pi_D = 3$, $\Pi_{COOP} = 1$, $F = 3$, $R = 0$, $\delta = 0.8$, which is roughly consistent with the values chosen by our predecessor (Ghebrihiwet, Motchenkova, 2010) .

It is trivial to show that with this set of parameters "Not Collude or Cooperate" will always be strictly dominated by all other strategies, and "Deviate and Reveal" will always dominate "Deviate and Not Reveal". Consequently, we are left with only the following strategies to analyze: CNR, CR, DR, COOPNR, COOPR.

We now find the conditions necessary for each of these strategies to be an equilibrium (Table 1):

Table 1. Conditions for equilibria

CNR: $\begin{cases} V_{CNR} > V_{CR}; \\ V_{CNR} > V_{DR}; \\ V_{CNR} > V_{COOPNR}; \\ V_{CNR} > V_{COOPR} \end{cases}$ => $\begin{cases} p < 0.75; \\ \alpha < \frac{9}{20p}; \\ \alpha < \frac{25}{68p}; \\ \alpha < \frac{2.5}{10p - 3}. \end{cases}$	CR: $\begin{cases} V_{CR} > V_{CNR}; \\ V_{CR} > V_{DR}; \\ V_{CR} > V_{COOPNR}; \\ V_{CR} > V_{COOPR} \end{cases}$ => $\begin{cases} p > 0.75; \\ \alpha < \frac{3}{5}; \\ \alpha < \frac{2.5}{7.5 - 3.2p}; \\ \alpha < \frac{5}{9}. \end{cases}$	DR: $\begin{cases} V_{DR} > V_{CNR}; \\ V_{DR} > V_{CR}; \\ V_{DR} > V_{COOPNR}; \\ V_{DR} > V_{COOPR} \end{cases}$ => $\begin{cases} \alpha > \frac{9}{20p}; \\ \alpha > \frac{3}{5}; \\ \alpha > \frac{2}{3.2p}; \\ \alpha > \frac{2}{3}. \end{cases}$
COOPNR: $\begin{cases} V_{COOPNR} > V_{CNR}; \\ V_{COOPNR} > V_{CR}; \\ V_{COOPNR} > V_{DR}; \\ V_{COOPNR} > V_{COOPR} \end{cases}$ => $\begin{cases} \alpha > \frac{25}{68p}; \\ \alpha > \frac{2.5}{7.5 - 3.2p}; \\ \alpha < \frac{2}{3.2p}; \\ p < \frac{15}{16}. \end{cases}$	COOPR: $\begin{cases} V_{COOPR} > V_{CNR}; \\ V_{COOPN} > V_{CR}; \\ V_{COOPN} > V_{DR}; \\ V_{COOPN} > V_{COOPNR} \end{cases}$ => $\begin{cases} \alpha > \frac{2.5}{10p - 3}; \\ \alpha > \frac{5}{9}; \\ \alpha < \frac{2}{3}; \\ p > \frac{15}{16}. \end{cases}$	---

With the above parameters, the subgame perfect equilibria of the model are as follows:

1) CNR - if $0 < p < 0.75$ and $0 < \alpha < \frac{25}{68p}$;

2) CR – if $0.75 < p \le 1$ and $0 \le \alpha < \min[\frac{2.5}{7.5-3.2p}; \frac{5}{9}]$;

3) COOPNR – if $68 < p < \frac{3}{3.2}$ and $\max\left[\frac{25}{68p}; \frac{2.5}{7.5-3.2p}\right] < \alpha < \frac{2}{3.2p}$;

4) COOPR – if $\frac{3}{3.2} < p \le 1$ and $\frac{5}{9} < \alpha < \frac{2}{3}$;

5) N – for all other conditions (as long as all the values of α_i and p_i fall into the segment [0; 1]).

Natalia S. Pavlova

National Research University Higher School of Economics (Moscow, Russia), Institute for Industrial and Market Studies, Laboratory for antimonopoly and competition policy, Researcher.
Russian Presidential Academy of National Economy and Public Administration (Moscow, Russia), Center for Competition and Economic Regulation Studies, Senior researcher.
Moscow Lomonosov State University (Moscow, Russia), Chair of Competition and Industrial Policy, Deputy head of the Chair.
E-mail: nspavlova86@gmail.com

Andrei Y. Shastitko,
Moscow Lomonosov State University (Moscow, Russia), Chair of Competition and Industrial Policy, Head of the Chair, Professor.
Russian Presidential Academy of National Economy and Public Administration (Moscow, Russia), Competition and Economic Regulation Research Center, Director.
National Research University Higher School of Economics (Moscow, Russia). Institute for Industrial and Market Studies. Senior scientist.
E-mail: saedd@mail.ru, Tel. +7(495)939-52-37