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Leniency programs and socially beneficial cooperation: Effects of type I errors

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Abstract

This study operationalizes the concept of hostility tradition in antitrust as mentioned by Oliver Williamson and Ronald Coase through erroneous law enforcement effects. The antitrust agency may commit type I, not just type II, errors when evaluating an agreement in terms of cartels. Moreover, firms can compete in a standard way, collude or engage in cooperative agreements that improve efficiency. The antitrust agency may misinterpret such cooperative agreements, committing a type I error (over-enforcement). The model set-up is drawn from Motta and Polo (2003) and is extended as described above using the findings of Ghebrihiwet and Motchenkova (2010). Three effects play a role in this environment. Type I errors may induce firms that would engage in socially efficient cooperation absent errors to opt for collusion (the deserved punishment effect). For other parameter configurations, type I errors may interrupt ongoing cooperation when investigated. In this case, the firms falsely report collusion and apply for leniency, fearing being erroneously fined (the disrupted cooperation effect). Finally, over-enforcement may prevent beneficial cooperation from starting given the threat of being mistakenly fined (the prevented cooperation effect). The results help us understand the negative impact that a hostility tradition in antitrust — which is more likely for inexperienced regimes and regimes with low standards of evidence — and the resulting type I enforcement errors can have on social welfare when applied to the regulation of horizontal agreements. Additional interpretations are discussed in light of leniency programs for corruption and compliance policies for antitrust violations.

JEL classification: D43, K21, L41
Keywords: antitrust, competition, collusion, cooperation agreements, leniency, enforcement errors, corruption, compliance policies

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1. Introduction

Cartels are considered to be one of the most dangerous types of antitrust law violations. The substantial harm that they can cause — extensively documented by Connor and Bolotova (2006) and many other researchers in subsequent publications — is only one part of the problem. The other part is that because cartels are considered to be an illegal (sometimes criminal) practice, their participants go to great lengths to hide the existence of such agreements, making this type of violation one of the most difficult for antitrust authorities to detect. Among the methods of uncovering information about cartels is active repentance in the form of leniency programs for cartel participants along with screening (Harrington, 2007).

As leniency programs (LP) are implemented in more and more countries, we find evidence of both their success and failure.[1] Researchers have noted many possible ambiguous effects such programs can have on firms' incentives. One of the topics that has not been sufficiently studied is the effect of type I errors on deterrence in the presence of LPs. This is supported by the recent study by Yusupova (2013), who found that in the Russian case, many agreements that were uncovered with the help of leniency are not hard-core cartels at all but other types of agreements (and not only horizontal ones), including those that can hardly be considered as restricting competition. De facto, this means that cartels as well as other horizontal agreements are not self-evident unless they are reduced to well documented cases of price-fixing and market-sharing.

This can be illustrated by some examples from the experience of the Russian antitrust authority — the Federal Antimonopoly Service. One of these is a 2009 case on the agreement between two banks — Bank Uralsib and Toyota Bank.[2] At that time, Toyota Bank did not yet have the necessary license for acquiring money sums from individuals. The process of obtaining that license could take up to two years, but Toyota Bank wanted to give out loans to individuals for the purpose of buying cars from Toyota. Toyota Bank entered into an agreement with Bank Uralsib, which agreed to open current accounts for individuals for the purpose of transferring to them the car loans that were taken out at Toyota Bank and managing all subsequent loan payments. This agreement included as a provision the obligation of Bank Uralsib to abstain from recommending to individuals their own bank as a source of car loans for buying Toyotas from official dealers. This agreement was found by the antimonopoly authority to be anticompetitive and harmful, but the case was closed because both banks pleaded guilty, applied for leniency and eliminated the offending clause in the agreement. However, the reason for the agreement and its nature leave considerable doubt concerning the qualification of the agreement as intentionally anticompetitive. Interestingly, the case was repeated in 2012, when a similar agreement between Bank Uralsib and Volkswagen Bank RUS was uncovered by the Russian FAS[3] —

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

[2] Decision of the FAS Russia on case No. 1 11/120-09 http://solutions.fas.gov.ru/documents/169-883e8928-b5c6-4b4b-8130-9fc856f10b5f

[3] Decision of the FAS Russia on case No. 1 11/67-12 http://solutions.fas.gov.ru/ca/upravlenie-kontrolya-finansovyh-rynkov/1-11-67-12

except this time neither of the companies applied for leniency or pleaded guilty, choosing instead to appeal the authority's decision in court. Although these two cases seem to be obvious candidates for closer study from the point of view of possible benefits of cooperation, they have not been rigorously studied by researchers. However, there are other examples of possible type I errors in qualifying horizontal agreements that have been discussed in the past few years. Some examples are related to a recent case on larger diameter pipes (LDP) initiated by the Federal Antimonopoly Service against Russian pipe producers in 2011. Among the evidence presented in the case were schedules for LDP delivery on OJSC Gasprom (main buyer) pipeline projects, signed by representatives of all four domestic producers. Initially, this fact was qualified as an agreement for market sharing *per se* and directly prohibited by Russian law "On the protection of competition." Only after more than one year (on March, 2013) of investigations were LDP producers acquitted due to a requalification of the agreement and implementation of the rule of reason.[4] There were no LP applications as such, but this is a good example of how the disclosure of a horizontal agreement that looks like a cartel is only the start in the long process of its interpretation.

The aim of this paper is twofold. First, we analyze how LPs 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 to be beneficial to social welfare. Second, we analyze whether the affected incentives could explain why the LP in Russia (and, probably, in other countries with emerging markets) resulted in such a structure of uncovered cases where the main part of the cases are not hard-core cartels.

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 firms: collude, compete, or enter 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 will give up efficiency-promoting cooperation agreements in equilibrium.

Additionally, we consider a set of implications for a wider area of research and practice. First, leniency programs analogous to those in antitrust exist in other areas, such as anticorruption legislation, and we examine how our results can apply to corruption schemes. Second, even if we stay in the realm of antitrust, leniency programs are not the only possible means for a firm to secure a reduction of fines: among the other means are antitrust compliance programs, which are currently widely discussed in Russia through the lens of their possible promotion in exchange for a discount of 1/8 of the antitrust fine (Shastitiko, 2016). We briefly examine the possible interplay between leniency and compliance in light of our results.

[4] For more detail, see, for example, Shastitko et al. (2014).

The paper is organized as follows. Section 1 gives a brief summary of the relevant literature. Section 2 introduces our main assumptions, the model and the equilibria. Section 3 describes the main results. Section 4 provides the discussion in terms of corruption and compliance. Section 5 concludes the paper.

2. Literature review

Multiple strands of literature have a direct bearing on our model. The first is the literature on LPs. We shall build upon the models of Motta and Polo (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 delineates some of the ambiguous effects of such programs (the "race to the courthouse", "cartel amnesty" and "deviator amnesty" effects) and shows which forms of the programs can encourage the prevalence of wanted effects. Aubert et al. (2006) take into account not only corporate LPs but also individual leniency and more specifically individual rewards for whistle-blowing, demonstrating the important effect individual leniency can have on destabilizing cartels but also pointing out its potential spillover effects. Harrington (2013) proposes a model of an LP when firms have private information regarding the likelihood of prosecution. Harrington and Chang (2015) study how an LP, given its possibly ambiguous consequences, affects the overall number of cartels in an economy.

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 and Leliefeld (2010) capture the effect of industry asymmetry, Motchenkova and van der Laan (2011) address the asymmetry of firms, while Herre and Rasch (2009) and Bos and Wandschneider (2011) tackle the problem of leniency for cartel ring-leaders. Roux and von Ungern-Sternberg (2007), Dijkstra and Schoonbeek (2010), Lefouili and Roux (2012), and Marshall et al. (2013) address the effects of leniency in multi-market settings. Houba et al. (2009) and Chen and Rey (2012) consider optimal amnesty for repeat violators, among other aspects.

While most of these works incorporate the assumption that the antitrust authority can make type II errors, mistakenly allowing violators to "walk free" (not literally acquitting them but also finding insufficient evidence that is not sustainable in the court room), almost none of them take into account the non-zero probability of type I errors, when the authority mistakenly fines innocent firms (or firms with minor violations). There is broad literature on judicial (enforcement) errors — wrongful conviction and prosecution (type I errors) and release of violators (II type errors). Unlike the straightforward conclusions on the applicability of punitive fines combined with the rather small probabilities of imposition (Becker, 1968, 1974) due to type II errors, type I errors change conclusions on integral deterrence effects of law enforcement under judicial errors. These ideas might be found in papers related to individual choice and the strategic interaction between economic exchange participants with third-party enforcer involvement (Garoupa and Rizolli, 2012; Rizolli and Saraceno, 2011; Rizolli and Stanca, 2012; Shastitko, 2011, 2013), although some doubts are expressed (Lando, 2006).

A broader view, combining issues of deterrence, optimal evidence and incentives for desirable behavior, is proposed by Kaplow (2011).

Can we find some theoretical support for the idea of deterrence intensity being reduced due to type I errors as applied to antitrust law enforcement with LPs? There are some applications of studies in antitrust law enforcement errors. For example, some asymmetry in the study of two types of errors and their effect on deterrence and socially beneficial cooperation is a topic actively debated, and the discussion might easily be found in the literature on antitrust economics and law and economics[5]. However, this is not the case for LPs under judicial errors of both types. An exception is Aubert et al. (2006), who established that the size of individual rewards should be limited to not 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 and 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.

The negative effects of type I errors in deterring cartels would not be as critical if not for the fact that so many forms of cooperation between competitors (so-called horizontal agreements) 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 economics (Williamson, 1985, 1996; Ménard, 2004). The term "hostility tradition" was introduced by Williamson to describe the situation of any economic practice deviating from a simplified standard, which is considered to be evidence of market power and exclusive (as opposed to exploiting) commercial practices that are harmful for competition and social welfare. This idea might also be found in the paper by Coase (1972) devoted to the achievements and development of industrial organization theory. Although 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 to what sort of consequences it can lead if cartels and socially beneficial cooperation between competitors are not sufficiently demarcated.

3. The model

3.1. The intuition

Before describing the model, let us examine very shortly the intuition behind the problem. If a firm is wrongfully accused and prosecuted for an offence and imputed with some evidence, it might expect a change in the balance of the expected costs and benefits of its actions. The violation of rules becomes relatively more attractive, and welfare-inducing agreements are concluded either more rarely or interrupted. If this is so, the effects of LPs devoted to reestablishing the one-shot prisoners' dilemma game between competitors might change compared to the presence of only type II errors. Intuitively, it is quite clear that several types

[5] Including such works as Posner (1998), Joskow (2002), Manne and Wright, (2009), Rill and Dillickrath (2009), and Immordino and Polo (2013).

of negative effects can arise, including not only false self-reporting and reporting by counter-agent of agreements but also abstaining from the use of particular clauses in contracts and refraining from concluding these contracts as a whole. That is why we can expect multiple forms of harm related not only to prospective market actors but also to principals of enforcement — tax payers. In our model, we limit ourselves only to direct effects. In any case, the intuition leaves us with some doubts as to what the structure of current and potential strategic interactions between firms will look like.

3.2. Assumptions

The presented 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 (2010) 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 (2003). They derive some interesting results, e.g., that innocent firms may use plea bargaining as insurance against a type I error. At the same time, this model does not allow us to analyze the self-reporting (including counter-part reporting) of cooperating firms. We extend the model by Ghebrihiwet and Motchenkova (2010) to take into account the effects of LPs on horizontal cooperation agreements that are beneficial to social welfare.

Additionally, the model by Ghebrihiwet and Motchenkova (2010) does not allow innocent firms to apply for leniency because there is no legal uncertainty on particular forms of market behavior. Instead, it 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, whereas 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. That is why the notion of evidence quality is important. 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 the model by Ghebrihiwet and Motchenkova (2010), the probabilities of type I and type II errors are the same across all possible behavioral strategies. We propose taking into account that the antimonopoly authority has some experience that allows it to distinguish different types of behavior on a market. In this way, the probability of a colluding firm being found guilty is higher than that for a firm that does not in fact violate the law. This point reflects some particularities of administrative procedures taken into account by the antitrust authority to initialize the case and to make decisions based on the collected and interpreted evidence.

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}). Because all firms are symmetric, they all choose the same strategy in equilibrium. The antitrust authority chooses an enforcement policy that can include the use of a LP. 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 ($0 \leq R < F$)[6] and the probabilities of firms being investigated and prosecuted.

We extend the model by Ghebrihiwet and Motchenkova (2010) by assuming that the probabilities of an investigation opening and ending in a conviction are different across different market strategies in the following way. 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, they are α_2 and p_2; for cooperating firms, they are α_3 and p_3, $\alpha_0 \neq \alpha_1 \neq \alpha_2 \neq \alpha_3$, $p_0 \neq p_1 \neq p_2 \neq p_3$.

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 the work of 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. It seems logical to assume that the lowest probabilities are applicable for firms that originally compete — that is, they neither collude nor cooperate on the market. In this case, not only is there no trace of any agreement, there is also no evidence of excessive profit. 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. Although the firm acted competitively in the first period by undercutting its rivals' price, it has still entered the agreement at some previous point in time — otherwise there

[6] Here we interpret the fine in an 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 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. 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 damage claims 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. In this way, the fact that the model explicitly deals with fines and not with other types of potential sanctions may also imply that the probabilities of these sanctions are very small.

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.

would be nothing from which to deviate. Therefore, some proof of the existence of a cartel agreement exists, even though the profits received by the 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: $\alpha_0 < \alpha_2 < \alpha_1$ and $p_0 < p_2 < p_1$.

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

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 (*ex post*) and interpreted as evidence of collusion. However, in the case of deviating, competition can be observed (as a process): behavior on the market shows that firms actively compete by undercutting each others' prices. In contrast, in the case of the deviating strategy, the available evidence that can be used as proof of collusion is only the agreement itself and during a limited period of time. In the case of cooperation, there is both an agreement and a market outcome that can resemble collusion[7]. 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 $\alpha_0 < \alpha_2 < \alpha_3 < \alpha_1$ and $p_0 < p_2 < p_3 < p_1$.

The timing of the game is as follows. The antitrust authority monitors the behavior of firms in the market, prioritizing the directions and scope of screening. 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 (not checking whether the confession is false). The firm that confessed receives a reduced fine and is made to compete in the current period. If none of the firms confess, 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 (it is not assumed that it can exit the market). 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.

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

3.3. Values of strategies

A. 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

[7] We assume that if specialized tests used by the antitrust authority, such as those described in Harrington (2007), exist, they are not known to the firms and therefore are not considered by them when choosing strategies.

an infringement and makes the firm pay the full fine F.[8] Because the firms in fact compete, they will not be able to provide evidence of collusion in exchange for leniency. In fact, false positives on the screening side cannot be compensated by access to leniency.

B. Collude and not reveal (CNR)

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

C. 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 R.

D. 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 $\Pi_D > \Pi_M$ for one period. Next period, the deviation will be observed by the rivals, and collusion will be terminated.

Π_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. Because the firm does not confess in period 1, the investigation lasts for two periods. In the second period, the firm, having deviated already, receives profit Π_N. The antitrust authority concludes the investigation, falsely establishing the fact of collusion with probability p_2, which results in the full fine F.

E. 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. Intuitively this way of behavior might be explained in terms of unfair competition with the use of LPs as an instrument to outperform rivals.

[8] The notion that competing firms can be falsely accused of having violated antitrust law is not a new one: for example, Rubin (1995) found that such type I errors appeared in 7 out of 23 antitrust cases analyzed. Recently, the Russian FAS has been under attack for its multitude of cases, many of which, researchers feel, might have been handled with excess strictness (see, for example, Avdasheva et al., 2015).

In the first period, the antitrust authority starts an investigation with probability α_2. The firm self-reports and receives the reduced fine R. Because 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 because it can use the initial agreement (even though it was not upheld) as proof of collusion.

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

F. 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 under some conditions cooperation — as a result of combining resources (selective systems to arrange interaction, joint planning, systems of information disclosure), the use of specialized mechanisms of governance, etc. — yields profits higher than competitive, but lower than collusive (monopoly) profits, thus $\Pi_{COOP} > \Pi_N$.

A different question is how the cooperative profit relates to the collusive profit.[9] In theory, any ratio is possible. Note further that collusive profit does not include any parts of cooperative profits because there is no welfare-enhancing agreements leading to any Schumpeterian innovations (product, process, resource, organization). 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 (for example, due to process innovation). Another possibility is that an increase in price will rise to reflect the enhanced product quality due to cooperation (and, correspondingly, increased willingness of consumers). At least one obvious example of $\Pi_{COOP} > \Pi_M$ is the case for radical process innovation, where the price might not be higher than the initial competitive price while the quantity is significantly larger than in the monopoly case. This case even allows the presence of a competitive frame for cooperating firms. 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 case of a cooperation agreement, not only is the profit higher, but the risk of being fined is simultaneously lower, so the cooperating strategy becomes dominant. The case we will focus on is $\Pi_{COOP} < \Pi_M$, and we shall examine it more closely.

[9] For the purpose of this article, we consider cooperating and colluding to be alternative strategies for a firm. We purposefully do not consider the option when firms "cooperate" and "collude" at the same time, that is when their agreement leads both to a decrease of costs and increase of price. This exclusion stems from one of the aims of this paper, which is to show the effects of type I errors in the case of leniency. When firms both raise prices and cut costs, the overall effect can be ambiguous and we would need additional assumptions to determine within our model whether an agreement is socially beneficial and whether the antitrust authority makes errors in classifying it. Nevertheless, incorporating such agreements in our model constitutes a possible line for further research.

The antitrust authority opens an investigation with probability α_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.

G. Cooperate and reveal (COOPR)

Here, again, the antitrust authority starts the investigation with probability α_3. However, 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), which is expressed in our model by the different probabilities of opening an investigation and finding an infringement for different strategies, but on the other hand, it cannot tell a cooperation agreement from a cartel agreement, even after "getting its hands on" the agreement itself? This is where what authors have called the "hostility tradition" in antitrust comes into play: antitrust authorities, when dealing with a practice that has attributes of possibly being anticompetitive, tend to interpret it as having an anticompetitive aim while simultaneously ignoring any other interpretation. In this case, type I errors, just like type II errors, can be made by antitrust authorities maximizing social welfare. We model the antitrust authority as having precisely this goal — maximizing social welfare. However, the real-world behavior of antitrust authorities makes us consider the possibility of type I errors as even more plausible — judging, for example, by the experience of antitrust enforcement in Russia (as not just a theoretical but quite a realistic perspective), 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 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 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 (which stems from the authority's assumed incentive structure).

Similarly to the model by 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	$V_{CNR} = \alpha_1\{\Pi_M + \delta[p_1(\Pi_N - F) + (1-p_1)\Pi_M]\} + (1-\alpha_1)(\Pi_M + \delta\Pi_M) + \delta^2 V_{CNR}$	$V_{CNR} = \frac{\Pi_N}{1-\delta} - \alpha_1 p_1 \frac{\delta(\Pi_M - \Pi_N + F)}{1-\delta^2}$
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	$V_{DR} = \alpha_2(\Pi_D - R) + (1-\alpha_2)\Pi_D + \delta V_R$	$V_{DR} = \Pi_D + \frac{1}{1-\delta} - (\delta\Pi_N - \alpha_2 R)$
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	$V_{COOPR} = \alpha_3(\Pi_N - R) + (1-\alpha_3)\Pi_{COOP}] + \delta V_{COOPR}$	$V_{COOPR} = \frac{\Pi_{COOP}}{1-\delta} - \alpha_3 \frac{\Pi_{COOP} - \Pi_N + R}{1-\delta}$

3.4. Subgame perfect equilibria

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

Following the discussion on the values of α and p presented in section 3.2, we will try to define the conditions for α and p that influence which strategy becomes dominant. To do this, for the 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 $\alpha_0 = 0.2\alpha$, $\alpha_1 = \alpha$, $\alpha_2 = 0.4\alpha$, $\alpha_3 = 0.6\alpha$, $p_0 = 0.2p$, $p_1 = p$, $p_2 = 0.4p$, and $p_3 = 0.6p$. As mentioned above, these values satisfy the conditions $\alpha_0 < \alpha_2 < \alpha_3 < \alpha_1$, $p_0 < p_2 < p_3 < p_1$, 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), corresponding to a 100% fine discount.

The appendix contains all the necessary calculations.

We find the values of α and p that cause certain strategies to dominate. For our chosen illustrative example (see Appendix), the equilibria are as follows:

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

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

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

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

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

4. Results and discussion

4.1. Characterization of subgame perfect equilibria

The model by 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 Fig. 1.

One of the main findings of Motta and Polo (2003) 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 do not reveal (*CNR* and *CR*). This happens when the probability of starting an investigation, α, is low. If at the same time the probability of successful prosecution (p) is low, then firms do not have an incentive to confess and we end up in the *CNR* area, where firms collude and do not reveal information about it. In contrast, 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*).[10]

The results are illustrated in Fig. 2.

The *N*, *COOPNR*, *COOPR*, *CNR*, and *CR* areas denote different types of equilibria that depend on the values of α 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*; thresh-

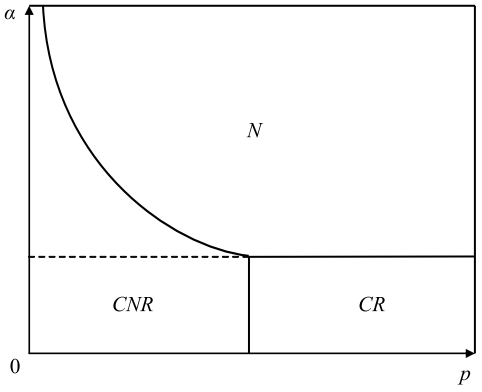

Fig. 1. The results of Motta and Polo (2003).

[10] 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, because in this way, it not only receives a deviator's profit but also exempts itself from paying a fine.

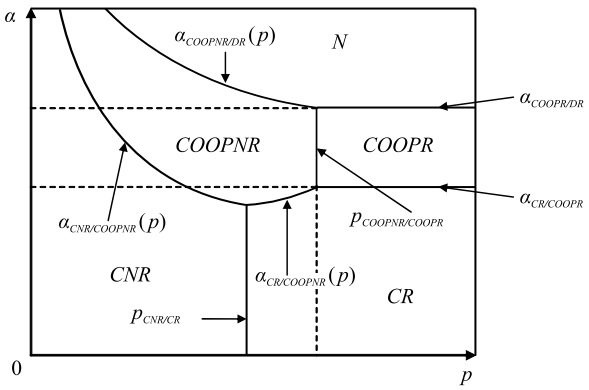

Fig. 2. Equilibria of the model in axes (α; p).

olds $\alpha_{CNR/COOPNR}(p)$, $\alpha_{CR/COOPNR}(p)$, $\alpha_{COOPR/DR}$ 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*.

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.

4.2. 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 remaining equilibria: CNR, CR and COOPNR.

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

$$V_{COOPNR} = \Pi_{COOP} + \delta\Pi_{COOP} + ... = \frac{\Pi_{COOP}}{1-\delta}. \quad (1)$$

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

First, because 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 to destroy the existing cooperation for one period. Similarly, *DNR* starts to dominate *DR*.

Second, because 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[11] (if $\Pi_{COOP} > \Pi_N$ 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.

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

Third, the ratio of the values of the *COOPNR* and *DNR* strategies 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 Fig. 3.

Finally, we illustrate the comparison of the results derived with and without the assumption of type I errors (Fig. 4). 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 the areas where collusion appears. Not all of this 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 — in this way, they at least compensate by receiving collusive profits.

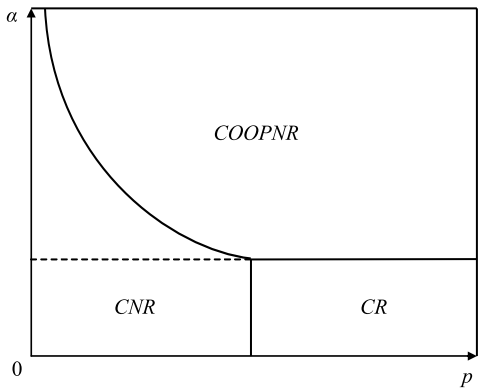

Fig. 3. Results of Motta and Polo (2003) with cooperation.

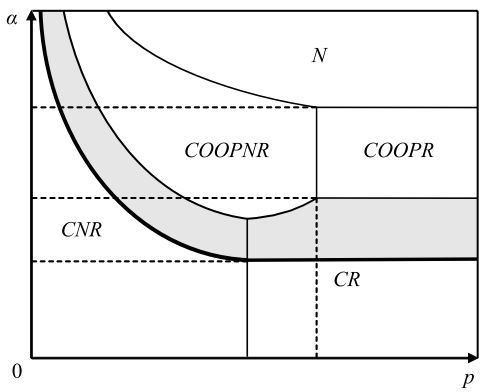

Fig. 4. Impact of type I errors on the effectiveness of leniency programs.

An effect that was not studied by Ghebrihiwet and Motchenkova (2010) and that has not yet been the object of systematic 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 arises 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 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 reconcile these two seemingly contradictory findings: in our model, these effects are not mutually exclusive, but the prevalence of one or the other depends on the deterrence parameters α and p. This leads us to

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.

4.3. 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 in which a confession is not 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, the chosen parameters ensure that *DNR* dominates *N*.

In this way, three types of equilibria are possible: where all firms collude and do not reveal, where all firms cooperate and do not reveal, and where firms compete. The results are illustrated in Fig. 5.

The labeled areas correspond with the equilibria in our main model with leniency. In the dark-grey area, the equilibrium in the absence of leniency is *CNR*;

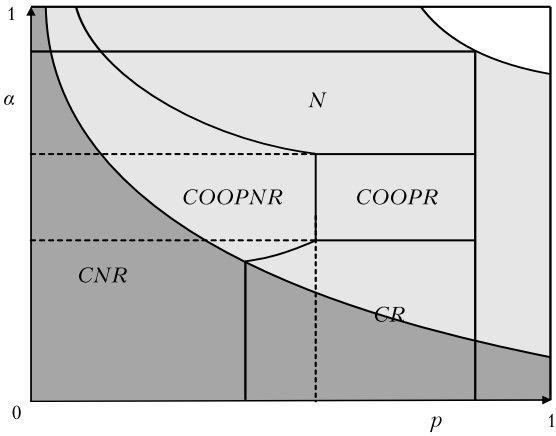

Fig. 5. Results of the model with and without leniency.

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 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.

First, we confirm the result obtained by Motta and Polo (2003). With the inclusion of leniency, the area where collusion can (in principle) be maintained becomes larger (transition from the dark-grey area to *CNR*+*CR*). However, the participants of the newly formed cartels prefer to collude and confess; in addition, 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*). That is why the presented model provides grounds to expect a more complicated picture as could be presupposed intuitively.

It is worth mentioning that in our model the "donor" area for collusion is the locus where in the absence of leniency, cooperation is 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 to insure themselves against possible unfair punishment (locus *COOPR*). This means that in case an investigation starts, the cooperation will break up. Because 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 in the area where cooperation can be maintained at all. 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, whereas the area where no cooperation arises increased in size.

The effects described above are summarized in

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

It is difficult to say whether the total effect on welfare will be negative or positive. With the introduction of leniency, the less harmful *CR* strategy partially replaces *CNR*, but the overall collusive area expands by reducing the potential for cooperation. In addition, incentives for choosing to compete grow, which, on its own, may be beneficial for welfare. Still, the possibilities of welfare-reducing effects should be enough to make regulators consider the importance of raising the standards of evidence, including access to relevant information and adequate interpretation by means of economic analysis while looking at horizontal agreements.

5. Discussion

5.1. Leniency and corruption

The topic of leniency has strong ties with that of corruption that are obviously underdiscussed. The link is two-fold. First, antitrust violations — primarily car-

tels and bid-rigging — are known to have strong correlations with corrupt practices. In public procurement, for example, collusion is often facilitated through government agents, and antitrust investigations often lead to uncovering cases of bribery and other types of corruption. For this reason, effective leniency programs contribute to the fight against corruption by helping in the acquisition of information about potential violations at a lower cost for the regulator. However, some complications can arise from the fact that when a firm applies for leniency, it can factor into its decision the risk of becoming subject to an anticorruption investigation. If corruption indeed took place, then in terms of modeling it could mean that the reduced fine would be greater than zero, and the effectiveness of leniency policies could be critically reduced. A potential solution would be to ensure that whoever is exempt from liability for an antitrust violation should also be guaranteed protection from sanctions for corruption. The legal mechanism for such a construct requires further discussion, but one point is that the whistle-blower should also be required to collaborate with authorities in investigating the corruption case to receive additional leniency. The discussion of this link between corruption and leniency programs is outside the scope of our paper.

Another aspect linking leniency for cartel participants and the fight against corruption is the fact that leniency programs are also widely used to uncover other types of violations, namely corruption schemes. The effectiveness of such programs can be unclear (for a review, see Berlin and Spagnolo, 2015), but an aspect that has not been previously studied is the effect of leniency on corruption, which in fact facilitates welfare-maximizing transactions. The fact that corruption can, under certain circumstances, promote efficiency has been widely debated, with proponents appealing to arguments ranging from the familiar "greasing the wheels" metaphor to more complicated ones, such as in Huntington (1968), and opponents drawing attention to disastrous long-term effects. A relevant concept would be one put forward by Basu (2011) — the category of "harassment bribes", or bribes that are given by actors to receive benefits to which they are already legally entitled. Assuming that the entitlement is derived from a social welfare-maximizing strategy, corruption becomes a less costly way to attain an efficient outcome in a rigid system, with no tendency towards positive change in the foreseeable future. If, by this logic, some forms of corruption can indeed promote efficiency, then treating all acts of corruption as *per se* illegal creates the risk of type I errors, interpreted not as wrongfully prohibiting a practice that is in fact legal but wrongfully prohibiting an efficiency-enhancing practice.

In that case, the introduction of leniency programs for acts of corruption can be modeled in a way similar to that which we use above, where collusion can be replaced, for example, by bribery with an inefficient outcome, and cooperation would be an act of efficiency-promoting corruption. We can easily envision a system of undiscriminating corruption, where bribes are part of the universally accepted rules of the game and even the most efficient companies participate in corrupt schemes, while the enforcement of anticorruption laws is selective (whether due to a lack of resources or due to political concerns). The "deviating" strategy also has a meaning because often corrupt relationships are shown to be susceptible to risks of opportunistic behavior on both sides (and consequently to

the "hold up" problem — see Buccirossi and Spagnolo, 2006). Differing probabilities of investigation and conviction would also still be rationalized in a system with only limited resources that can be devoted to fight corruption: while it is impossible to monitor all transactions for potential corruption all the time, it makes sense that transactions that lead to socially unbeneficial outcomes (e.g., receiving a bribe to appoint an inefficient company to be the supplier of certain goods for the government, resulting in disruptions of contracts) will draw more attention from the authorities than transactions that eventually lead to beneficial outcomes (e.g., receiving a bribe for appointing that same contract to the most efficient company on the market, following which the contract is fulfilled without failure and for a low price).

With these assumptions, the mechanics of the model will remain the same, while the results can gain an additional interpretation. Assuming corruption can be welfare maximizing (even if only in the short term), introducing a leniency program could not only induce firms to employ bribery to gain benefits to which they have no right in the first place (moving from welfare-beneficial to welfare-unbeneficial corruption as an analogue of the "deserved punishment" effect) but also destabilize existing efficient, but illegally established schemes (as in the "disrupted cooperation effect") and preclude firms from engaging in welfare-maximizing activities if the only way to access them is by corruption (as in the "prevented cooperation" effect).

5.2. Leniency and compliance

As the idea of encouraging companies to implement antitrust compliance policies, possibly by way of providing a reduction of fines, becomes more and more popular in Russia, it is interesting to look at the possible consequences of such a measure, given what we know about the effects of leniency programs and how these two instruments can enforce or hinder each other.

On the first point, it is worth noting that our results highlight the risks of importing institutions without sufficiently taking into account the nuances of the local institutional environment, including working mechanisms of rules enforcement. Antitrust norms rely heavily upon economic analysis and expert judgment, and countries that have relatively less experience in applying the specific methods of economic analysis used in antitrust, as well as countries with insufficient resources dedicated to antitrust enforcement, run a higher risk of type I errors. Knowing this, firms tend to use all the instruments available to them to minimize the risk of wrongful conviction — and sometimes it becomes economically feasible to use as the means of insurance some instruments that were initially not developed for these purposes. Consequently, while antitrust fines in Russia remain large and an asymmetry of information persists between firms and the antitrust authority as to what constitutes a violation (taking into account the general assumption that norms do not necessarily promote the most efficient of all possible outcomes), it is quite possible to expect that compliance programs might be used by firms for which they were not initially meant (i.e., firms with low risks of antitrust violations). All in all, this might result in an additional cost for business (the cost of devising and implementing an unnecessary compliance program) and, eventually, a devaluation of the whole concept

of compliance programs — that is, unless specific measures are taken to curb these possible effects.

The second point might be better understood if we relax the assumption of a firm functioning as a "black box" with the single purpose of maximizing profit and revert to an approach more in line with methodological individualism. Assuming that an asymmetry of information is present between the owners of a firm and its managers, as well as between top-managers and managers and so on, and a discrepancy exists between the goals of the principals and the agents on different levels, adopting an antitrust compliance program that identifies not only external antitrust risks (such as the types of violations that are most likely to occur based on the market structure and market position of the firm) but also internal ones and develops the necessary corporate procedures to minimize those risks seems both individually and socially beneficial. Firms benefit from an individual reduction of the probability of conviction, society benefits from a reduced probability of violations, and corporate procedures provide the necessary sources of evidence to keep the costs of possible investigations down, including the costs of identifying the individuals responsible, which can be critical for criminal sanctions. In practice, the effects of such policies can be ambiguous depending on, among other things, the design of the liability rules (Buccirossi and Spagnolo, 2008; Shastitko, 2016).

If a compliance policy is in place, it may complicate the matter of leniency. First, in countries where both corporate and individual leniency programs exist, if an internal investigation follows a certain procedure and takes time, then a company faces an additional risk of individual whistle-blowers applying for individual leniency throughout the time of such an investigation. If an individual self-reports and the antitrust authority finds out that the company is still investigating his behavior, which is why it has not applied for corporate leniency, the question arises of whether the company should be punished as severely as if an internal investigation was not underway or if their compliance policy was inefficient in preventing and uncovering the violation.

The intuition behind possible type I errors in the case of compliance policies — the company mistakenly self-diagnosing a violation — and their potential effects on owners, managers at different levels and employees, as well as the actions of the company as a whole, remains an issue for further discussion. We hope that these questions will be expanded upon in future research.

6. Conclusions

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 use of LPs. There are three 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 — resulting from the incentive of a firm to switch from competition or socially beneficial cooperation to collusion in order to guarantee that the punishment they could possibly receive will be deserved. In Fig. 5, this is the intersection of the light-grey area and *CR* area.

(2) the disrupted cooperation effect — resulting from cooperation agreements becoming destabilized due to the incentive for firms to make false confessions to avoid undeserved punishment. This effect is illustrated by the *COOPR* area, where in the absence of a leniency program, cooperation is upheld.

(3) the prevented cooperation effect — resulting from the fact that any type 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 probability of being punished. Consequently, firms start to prefer not to engage in any sort of agreements with competitors (the light-grey area *N* in Fig. 5) — a factor that impedes technological progress and innovation and hinders the inflow of investment.

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

Our results have certain implications in connection with anticorruption law and antitrust compliance policies. It can be shown that by a logic similar to that which we apply to collusion, leniency programs for corruption with type I errors can impair some socially beneficial forms of activity. As for compliance policies, they too may have ambiguous effects and be applied erroneously, which merits further consideration from antitrust authorities on how to design corresponding liability rules and curb undesirable incentives.

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Appendix

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 $\alpha_0 < \alpha_2 < \alpha_3 < \alpha_1$ and $p_0 < p_2 < p_3 < p_1$, where $\alpha_i \in [0, 1]$ and $p_i \in [0, 1]$. Let $\alpha_1 = \alpha$ and $p_1 = p$, while $\alpha \in [0, 1]$ and $p \in [0, 1]$. We will now assume that $\alpha_0 = 0.2\alpha$, $\alpha_2 = 0.4\alpha$, $\alpha_3 = 0.6\alpha$, $p_0 = 0.2p$, $p_2 = 0.4p$, and $p_3 = 0.6p$.

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

1. Conditions for "Neither Collude nor Cooperate" being dominant:

$$\begin{cases} V_N > V_{CNR} \\ V_N > V_{CR} \\ V_N > V_{DNR} \\ V_N > V_{DR} \\ V_N > V_{COOPNR} \\ V_N > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha > \frac{(\Pi_M - \Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0{,}96F)} \\ \alpha > \frac{(\Pi_M - \Pi_N)(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0{,}04p\delta F} \\ \alpha > \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0{,}12p\delta F} \\ \alpha > \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0{,}4R(1+\delta) - 0{,}04p\delta F} \\ \alpha > \frac{(\Pi_{COOP} - \Pi_N)(1+\delta)}{p\delta[0{,}36\Pi_{COOP} - 0{,}36\Pi_N + 0{,}32F]} \\ \alpha > \frac{(\Pi_{COOP} - \Pi_N)(1+\delta)}{0{,}6(\Pi_{COOP} - \Pi_N + R)(1+\delta) - 0{,}04p\delta F} \end{cases} \quad \text{(A1)}$$

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

$$\begin{cases} V_{CNR} > V_N \\ V_{CNR} > V_{CR} \\ V_{CNR} > V_{DNR} \\ V_{CNR} > V_{DR} \\ V_{CNR} > V_{COOPNR} \\ V_{CNR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_M - \Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0{,}96F)} \\ p < \frac{(\Pi_M - \Pi_N + R)(1+\delta)}{\delta(\Pi_M - \Pi_N + F)} \\ \alpha < \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0{,}84F)} \\ \alpha < \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + F) - 0{,}4R(1+\delta)} \\ \alpha < \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{p\delta(\Pi_M - 0{,}64\Pi_N + 0{,}64F - 0{,}36\Pi_{COOP})} \\ \alpha < \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{p\delta(\Pi_M - \Pi_N + F) - 0{,}6(\Pi_{COOP} - \Pi_N + R)(1+\delta)} \end{cases} \quad \text{(A2)}$$

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

$$\begin{cases} V_{CR} > V_N \\ V_{CR} > V_{CNR} \\ V_{CR} > V_{DNR} \\ V_{CR} > V_{DR} \\ V_{CR} > V_{COOPNR} \\ V_{CR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_M - \Pi_N)(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0{,}04p\delta F} \\ p > \frac{(\Pi_M - \Pi_N + R)(1+\delta)}{\delta(\Pi_M - \Pi_N + F)} \\ \alpha < \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0{,}16p\delta F} \\ \alpha < \frac{\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N}{\Pi_M - \Pi_N + 0{,}6R} \\ \alpha < \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0{,}36p\delta(\Pi_{COOP} - \Pi_N + F)} \\ \alpha < \frac{\Pi_M - \Pi_{COOP}}{\Pi_M - 0{,}6\Pi_{COOP} - 0{,}4\Pi_N + 0{,}4R} \end{cases} \quad \text{(A3)}$$

4. Conditions for "Deviate and Not Reveal" being dominant:

$$\begin{cases} V_{DNR} > V_N \\ V_{DNR} > V_{CNR} \\ V_{DNR} > V_{CR} \\ V_{DNR} > V_{DR} \\ V_{DNR} > V_{COOPNR} \\ V_{DNR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0{,}12p\delta F} \\ \alpha > \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + 0{,}84F)} \\ \alpha > \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{(\Pi_M - \Pi_N + R)(1+\delta) - 0{,}16p\delta F} \\ p < \frac{R(1+\delta)}{0{,}4\delta F} \\ \alpha > \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta[0{,}36\Pi_{COOP} - 0{,}36\Pi_N + 0{,}2F]} \\ \alpha > \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{0{,}6(\Pi_{COOP} - \Pi_N + R)(1+\delta) - 0{,}16p\delta F} \end{cases} \quad \text{(A4)}$$

5. Conditions for "Deviate and Reveal" being dominant:

$$\begin{cases} V_{DR} > V_N \\ V_{DR} > V_{CNR} \\ V_{DR} > V_{CR} \\ V_{DR} > V_{DNR} \\ V_{DR} > V_{COOPNR} \\ V_{DR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_D - \Pi_N)(1-\delta^2)}{0{,}4R(1+\delta) - 0{,}04p\delta F} \\ \alpha > \frac{(\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta(\Pi_M - \Pi_N + F) - 0{,}4R(1+\delta)} \\ \alpha > \frac{\Pi_M - (1-\delta)\Pi_D - \delta\Pi_N}{\Pi_M - \Pi_N + 0{,}6R} \\ p > \frac{R(1+\delta)}{0{,}4\delta F} \\ \alpha > \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{0{,}36p\delta(\Pi_{COOP} - \Pi_N + F) - 0{,}4R(1+\delta)} \\ \alpha > \frac{\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N}{0{,}6\Pi_{COOP} - 0{,}6\Pi_N + 0{,}2R} \end{cases} \quad \text{(A5)}$$

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

$$\begin{cases} V_{COOPNR} > V_N \\ V_{COOPNR} > V_{CNR} \\ V_{COOPNR} > V_{CR} \\ V_{COOPNR} > V_{DNR} \\ V_{COOPNR} > V_{DR} \\ V_{COOPNR} > V_{COOPR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_{COOP} - \Pi_N)(1+\delta)}{p\delta[0{,}36\Pi_{COOP} - 0{,}36\Pi_N + 0{,}32F]} \\ \alpha > \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{p\delta(\Pi_M - 0{,}64\Pi_N + 0{,}64F - 0{,}36\Pi_{COOP})} \\ \alpha > \frac{(\Pi_M - \Pi_{COOP})(1+\delta)}{p\delta(\Pi_M - 0{,}64\Pi_N + 0{,}64F - 0{,}36\Pi_{COOP})} \\ \alpha < \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{p\delta[0{,}36\Pi_{COOP} - 0{,}36\Pi_N + 0{,}2F]} \\ \alpha < \frac{(\Pi_{COOP} - (1-\delta)\Pi_D - \delta\Pi_N)(1+\delta)}{0{,}36p\delta(\Pi_{COOP} - \Pi_N + F) - 0{,}4R(1+\delta)} \\ p < \frac{(\Pi_{COOP} - \Pi_N + R)(1+\delta)}{0{,}6\delta(\Pi_{COOP} - \Pi_N + F)} \end{cases} \quad \text{(A6)}$$

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

$$\begin{cases} V_{COOPR} > V_N \\ V_{COOPR} > V_{CNR} \\ V_{COOPR} > V_{CR} \\ V_{COOPR} > V_{DNR} \\ V_{COOPR} > V_{DR} \\ V_{COOPR} > V_{COOPNR} \end{cases} \Rightarrow \begin{cases} \alpha < \frac{(\Pi_{COOP}-\Pi_N)(1+\delta)}{0{,}6(\Pi_{COOP}-\Pi_N+R)(1+\delta)-0{,}04p\delta F} \\ \alpha > \frac{(\Pi_M-\Pi_{COOP})(1+\delta)}{p\delta(\Pi_M-\Pi_N+F)-0{,}6(\Pi_{COOP}-\Pi_N+R)(1+\delta)} \\ \alpha > \frac{\Pi_M-\Pi_{COOP}}{\Pi_M-0{,}6\Pi_{COOP}-0{,}4\Pi_N+0{,}4R} \\ \alpha < \frac{(\Pi_{COOP}-(1-\delta)\Pi_D-\delta\Pi_N)(1+\delta)}{0{,}6(\Pi_{COOP}-\Pi_N+R)(1+\delta)-0{,}16p\delta F} \\ \alpha < \frac{\Pi_{COOP}-(1-\delta)\Pi_D-\delta\Pi_N}{0{,}6\Pi_{COOP}-0{,}6\Pi_N+0{,}2R} \\ p > \frac{(\Pi_{COOP}-\Pi_N+R)(1+\delta)}{0{,}6\delta(\Pi_{COOP}-\Pi_N+F)} \end{cases} \quad \text{(A7)}$$

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

Depending on the specific values of profits, fines and the 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 $\Pi_N = 0$, $\Pi_M = 1.5$, $\Pi_D = 3$, $\Pi_{COOP} = 1$, $F = 3$, $R = 0$, and $\delta = 0.8$, which are roughly consistent with the values chosen by our predecessor (Ghebrihiwet, Motchenkova, 2010).

It is trivial to show that with this set of parameters "Neither Collude nor 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 A1).

Table A1
Conditions for equilibria.

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

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

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

2) *CR* $0.75 < p \leq 1$ and $0 < \alpha < \min\left[\frac{2.5}{7.5-3.2p}; \frac{5}{9}\right]$;

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

4) *COOPR* $\frac{3}{3.2} < p \leq 1$ 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]).