Penalising on the basis of the severity of the offence:

A sophisticated revenue-based cartel penalty

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Abstract

We propose a new penalty regime for cartels in which the penalty *base* is the revenue of the cartel but the penalty *rate* increases in a systematic and transparent way with the cartel overcharge. The proposed regime formalises how revenue can be used as the base while taking into account the severity of the offence. We show that this regime has better welfare properties than the *simple* revenue-based regime under which the penalty rate is fixed, while having relatively low levels of implementation costs and uncertainty. We conclude that the proposed penalty regime deserves serious consideration by Competition Authorities.

JEL Classification: L4 Antitrust Policy, K21 Antitrust Law, D43 Oligopoly and Other Forms of Market Imperfection.

Keywords: Antitrust Enforcement, Antitrust Penalties, Antitrust Law, Cartels.

1. Introduction

In the majority of jurisdictions, including the European Commission, the corporate fine for collusion is based on the revenue of the colluding firms.[4] As in the rest of the literature we define "simple" revenue-based penalty regimes as those in which the penalty to be applied in any given cartel case is determined by multiplying the revenue that was earned by the cartel by a fixed penalty rate that is the same in all cases. As identified by Bageri et al. (2013) and Katsoulacos and Ulph (2013) this regime has the poor welfare property of inducing cartel prices above the monopoly level. On the other hand, it is attractive due to its transparency and ease of implementation as revenue data are generally publicly available.

In practice, many CAs that use the simple revenue-based penalty regime start from a fixed baseline penalty rate which is adjusted in individual cases to take into account a number of "mitigating and aggravating factors": One of these factors may be the severity of the offence as reflected in the size of the cartel overcharge.[5] However, these "mitigating and aggravating factors" can cover a range of non-price behaviours and are taken into account in a non-systematic, largely *ad hoc* manner that does not allow firms to foresee exactly how the penalty rate will be adjusted in their case if they were found to violate the law. Hence, it lacks transparency and it is impossible to establish what effect it has on cartel pricing and deterrence.

In our proposed *sophisticated revenue-based penalty* regime the penalty *base* remains cartel revenue while the penalty *rate* that is applied to that base is an increasing function of the percentage cartel overcharge. This function is the same across all cases. It can be thought of as

[4]See e.g. ICN report (2008, 2017), Bos and Schinkel (2006), Bageri et al. (2013), Katsoulacos and Ulph (2013) or Katsoulacos et al. (2015).

[5] We recognise that another dimension of severity is recidivism. While we have related work that takes this into account – see Katsoulacos et al. (2016) – including it in the context of penalty design introduces a degree of history dependence which makes the analysis intractable, so we leave analysis of this issues to future research.

a refinement of the *simple* revenue-based penalty regime. By continuing to use actual cartel revenue as the penalty base it retains its attractive implementation property of using publicly available data. At the same time it adjusts the penalty rate to be applied in each case with the severity of the offence, but in way that is more formal and systematic, and so has better transparency properties than the widely used version of the simple revenue-based regime.[6]

Furthermore, we show that our proposed regime has better welfare properties. We establish a precise condition that shows that – provided the percentage rate at which the penalty rate is increased with the overcharge is sufficiently large – within the class of models that we consider, the cartel price will be below the monopoly price in every industry. A simple linear penalty rate function, under which the penalty rate is proportional to the overcharge, will meet this condition.

Turning to deterrence, we show that the simple revenue-based penalty has the additional unattractive welfare feature that the degree of deterrence it achieves varies across industries (within the class of industries we consider) inversely with the monopoly overcharge in that

[6]The issues of transparency, predictability of legal sanctions and legal certainty (or discretion) are discussed extensively in the ICN report (2008) that is based on the survey conducted by the ICN among the CAs. Discussion on pages 12 and 13 of this report suggests that transparency and legal certainty are preferred fundamental legal principles, which also help reduce litigation costs. In particular, it is mentioned that in jurisdictions, where sufficiently high sanctions are available (such as the US and the EU), the higher degree of certainty with respect to how fines are determined is preferred. The report also mentions that in some jurisdictions CAs take the view that risk-averse managers may be more deterred by a penalty regime that has more uncertainty. But at the same time it warns that CAs in these jurisdictions would have to incur higher costs to justify their 'decisions in front of the bodies that approve the agency's proposal or review the agency's decision'. The report concludes that 'the less discretion in determination of fines by the agency, the lower the degree of litigation on the amount of the fine by companies or individuals who have been fined. Enforcers in jurisdictions with uncertainty as to how fines are determined may also face public criticism of their fining system as subjective or arbitrary.'

industry. On the other hand, the degree of deterrence that is achieved by the linear sophisticated revenue-based regime is the same across all the industries within the class we consider. We show that compared to any given simple revenue-based regime the linear sophisticated penalty regime can achieve better deterrence for all of the industries with a monopoly overcharge above any given target level. Hence, our proposed regime will achieve better deterrence exactly in the industries where the harm to consumers is higher.

Finally, we recognise that there are other implementation and transparency issues with our proposed penalty regime – in particular those related to estimation of cartel overcharges. We argue that these can be exaggerated, and that, given its superior performance in terms of cartel prices and deterrence the new regime deserves serious consideration as a replacement for the current simple revenue-based penalty regime.[7]

Section 2 establishes our analytical framework and provides a detailed analysis of the price effects and deterrence properties of the two penalty regimes. Section 3 discusses *implementation* aspects of the two regimes and the difficulties that may arise in relation to estimation of the overcharge, which is required for the sophisticated revenue-based, but not for

[7] It should be clear that our paper is a simple piece of advocacy for replacing the existing penalty regime with a better one. We do not attempt to derive any sort of optimum penalty regime. This is because (i) we do not know what is the right objective function for CAs that encompasses welfare, implementation and transparency concerns; and (ii) we do not know what is the appropriate distribution of cartel cases across different industries. As a matter of advocacy we think that it is better to present CAs with a single alternative that offers a refinement of the currently employed system: Our alternative allows a welfare improvement in terms of the reduction of consumer harm and at the same time remains transparent and easy to implement. As such our paper is consistent with a wide range of recent literature that recognises that penalty setting is an inherently second-best exercise. See for example: Bos and Schinkel (2006), Buccirossi and Spagnolo (2007), Schinkel (2007), Veljanovski (2007), Connor and Lande (2008), Allain et al. (2011), Bageri et al. (2013), Katsoulacos et al. (2015), Spagnolo and Marvão (2016), Dargaud et al. (2016), or Houba et al. (2018).

the simple revenue-based regime. Section 4 considers a range of possible extensions to our framework and how they affect our results, while Section 5 concludes.

2. Comparison of Regimes in terms of their Welfare Properties

In this section we undertake a systematic comparison of the welfare properties of the simple revenue-based penalty regime against a sophisticated revenue-based regime. We employ the widely used framework for analysing cartels and cartel enforcement, which has homogeneous products and constant marginal costs.[8] In contrast to much of this literature, which considers a single representative industry, in this paper we recognise that, for transparency and implementation reasons, a penalty policy should not depend on specific industry characteristics (e.g., demand elasticity). So we impose the restriction that the ***same*** penalty function has to apply across the full range of industries within the class specified above: homogeneous product and constant marginal cost.

2.1 *Model Setup*

The model is the repeated game model of cartel formation and pricing behaviour that is employed in Katsoulacos et al. (2015).[9] There is an economy comprising a range of industry types in each of which there is a homogeneous product with a decreasing and weakly concave demand function $Q(p)$, while production is carried out under constant unit costs $c>0$.

[8] See, e.g., Block et al. (1981), Tirole (1988, ch. 6), Chen and Rey (2013) or Katsoulacos and Ulph (2013). The homogeneous products/constant marginal costs framework has its limitations. However, what makes it such a powerful workhorse model is that it has the feature that in the absence of collusion competition is intense and the incentives to form a cartel are strongest. So it is important to test the effectiveness of penalty regimes in such an environment.

[9] A similar repeated game model has been employed in, e.g., Houba et al. (2010, 2018) or Bos et al. (2018).

Associated with this demand function is the elasticity $\eta(p) = -\frac{pQ'(p)}{Q(p)} > 0$, which we assume has the property

$$\eta(p) \text{ is non-decreasing in } p \text{ and } \exists \tilde{p} \geq 0 \text{ s.t. } \eta(p) > 1 \; \forall p > \tilde{p}. \quad (1)$$

An industry type is defined by the pair $\{c, Q(\cdot)\}$. For each industry type there is a range of industries that differ in the number of firms – $n \geq 2$ – that operates in that industry.

Similar to Chen and Rey (2013) or Bos et al. (2018) the form of competition in each industry is Bertrand competition. So in the absence of collusion the Nash equilibrium "but-for" price is given by $p^B = c$. p^M denotes the monopoly price. It also follows from our assumptions that for a cartel to be able effectively to maintain its price above the "but-for" level all firms in an industry have to be in the cartel.

If a cartel forms and sets a price $p > c$, then the percentage overcharge is $\theta = (p - c)/c$. So the price is given by $p = c(1+\theta)$. For any given overcharge set by a cartel the associated industry operating profits and revenue will be:

$$\pi(\theta) = c\theta Q\big(c(1+\theta)\big) \text{ and } R(\theta) = c(1+\theta)Q\big(c(1+\theta)\big). \quad (2)$$

There is a Competition Authority (CA) that investigates, discovers, prosecutes, and penalises cartels. As explained above, we focus on the following two penalty regimes:

(a) *Simple Revenue-Based Penalty Regime*, R. Here the penalty base is cartel revenue – $R(\theta)$ – to which a penalty rate $\rho_R > 0$ is applied. The penalty rate is the same across all cases and industries. So the financial penalty imposed under this regime will be

$$F_R(\theta) = \rho_R R(\theta). \quad (3)$$

(b) *Sophisticated Revenue-Based Penalty Regime*, SR. Here the penalty base is once again cartel revenue, but now the penalty rate applied to that base is a non-decreasing function

of the cartel overcharge $\rho_{SR}(\theta) > 0$, where the function $\rho_{SR}(\theta)$ is *the same across all industries*. So the financial penalty imposed under this regime will be:[10]

$$F_{SR}(\theta) = \rho_{SR}(\theta) R(\theta). \tag{4}$$

Let β – $0 \le \beta < 1$ – denote the probability that in each period a cartel is detected, successfully prosecuted, and penalised. As is common in the literature on the design of penalties we assume that β is independent of θ, and, moreover, its value is common knowledge. In addition, as in Katsoulacos et al. (2015), we assume that $\beta\rho_R < 1$. The properties of the function $\rho_{SR}(\theta)$ will be explored systematically in the next sub-section.

As in Motta and Polo (2003), Chen and Rey (2013), or Katsoulacos et al. (2015) we assume that following a successful prosecution the cartel immediately re-establishes itself.[11] Given this and our other assumptions, it follows that the expected present value of profits *for a single firm* that is a member of a cartel in a given industry that has set an overcharge θ and faces the penalty regime $r \in \{R, SR\}$ is given by

$$V_r(\theta) = \frac{\pi(\theta) - \beta F_r(\theta)}{n(1-\delta)}. \tag{5}$$

[10] Note that in practice cartel duration will influence the size of penalties. It is difficult formally to introduce the impact of fines that depend on cartel duration in the stationary repeated-games framework. However, its influence will be exactly the same on the simple revenue-based and the sophisticated revenue-based penalties (as in both cases per period penalties will have to be adjusted by multiplying by the duration of the offence) and, hence, will not affect the comparison between them.

[11] A different assumption, where following a prosecution the cartel never forms again, has been made in a number of contributions, such as, e.g., Harrington (2004) or Bos et al. (2018). In Katsoulacos et al. (2016) we unify the two different assumptions by looking at the probability of re-emergence of collusive activity following successful prosecution. This generalization produces more complex formulae for cartel value *V*(.) but does not affect the main qualitative results of the current paper, so we stick with the simpler assumption.

$\delta, 0 < \delta < 1$ is the discount factor. As in Katsoulacos et al. (2015), $\Delta \equiv n(1-\delta)$ denotes the *intrinsic difficulty* of holding the cartel together. We assume that for each industry type $\{c, Q(.)\}$ there is continuum of possible industries $\{c, Q(.), \Delta\}$, where we assume that Δ is uniformly distributed on [0,1].[12]

Following the standard grim-trigger strategy profile, firms collude on the cartel overcharge, θ, in the first period and continue setting θ as long as no firm defects. If a firm defects from the cartel it sets an overcharge below the cartel overcharge, and, for a single period takes the entire industry profits. Any deviation is punished by having the industry revert to competition at price *c*, for ever more. We also assume that the defecting firm is immune from any future prosecution by the CA.[13]

Since the overcharge that is set by a cartel could be above the monopoly overcharge – $\theta^M = \arg\max \pi(\theta)$ – a defecting firm that tries to make the maximum profits in the single period will set the monopoly overcharge whenever the cartel overcharge is above the monopoly overcharge, but will set an overcharge just a fraction below the cartel overcharge whenever this is at or below the monopoly overcharge, thereby capturing the entire cartel profits. So defection profits are

[12] As will shortly become clear, even in the absence of a CA stable cartels can only exist if $\Delta \leq 1$, so in order to understand the deterrence effects of a CA that operates under different penalty regimes it makes sense to restrict attention to the set [0,1]. The assumption of uniformity is made purely for convenience and can be replaced by a more general function without at all affecting the conclusions.

[13] While the qualitative nature of our results is largely unaffected by this assumption, we recognise that in practice this will not always be the case. However this assumption is made in many previous contributions by e.g. Motta and Polo (2003), while Spagnolo (2004) shows that not penalizing price deviating firms is the ideal policy. The reference to "any" future prosecution acknowledges that we are ignoring recidivism – see footnote 6.

$$\pi^d(\theta) = \begin{cases} \pi(\theta^M), & \theta > \theta^M \\ \pi(\theta), & \theta \le \theta^M \end{cases} . \quad (6)$$

For a cartel to be stable it has to satisfy the cartel stability condition:

$$V_r(\theta) \ge \pi^d(\theta). \quad (7)$$

Although we recognise that, by the Folk Theorem, a range of possible cartel overcharges could potentially be equilibria, we follow the existing literature on the design of cartel policy and assume that the overcharge set by a cartel facing penalty regime, *r,* is that which maximises $V_r(\theta)$ subject to $\theta \ge 0$ and the stability condition (7). We denote this by θ_r^C.[14] There are two cases to consider:

If the stability condition does not bind, then:

$$\theta_r^C = \hat{\theta}_r^C = \arg\max\left[\pi(\theta) - \beta F_r(\theta)\right] \quad (8)$$

and is independent of Δ, though it depends on the industry type.

On the other hand, if the stability condition binds, then θ_r^C is the solution to

$$\pi(\theta) = \beta F_r(\theta) + \Delta\pi^d(\theta), \quad (9)$$

and so is a function of Δ as well as the *industry type*.

Finally, we let $\bar{\Delta}_r$ be the maximum critical value of Δ such that, under penalty regime *r*, either the stability condition or the non-negative overcharge constraint binds.[15] Clearly if there were no CA - and so $\beta = 0$ - then a cartel would always set the monopoly overcharge and the maximum critical value of Δ would be 1. Whereas, once there is an active CA that

[14] Note that concavity of cartel value function *V(θ)* ensures the existence of the unique solution for overcharge that maximizes expression in (5). In what follows we assume that this condition is satisfied.

[15] The maximum critical level of difficulty – Δ – is the direct analogue of the minimum critical discount rate that is used in much of the literature.

enforces penalties on non-defecting cartel members we must have $\bar{\Delta}_r < 1$. So for each industry type we can define the *degree of deterrence* that is achieved by penalty regime r, D_r, as the fraction of industries of that type in which cartels would have formed in the absence of a CA in which they do not form given the presence of a CA operating penalty regime *r*. Formally:

$$D_r = 1 - \bar{\Delta}_r \ . \tag{10}$$

Having established the framework, we now investigate how both the cartel overcharge and the degree of deterrence vary depending on which of the two penalty regimes that we described above is employed by the Competition Authority.

2.2 *Cartel Pricing*

As discussed above there are potentially two types of solution: those where the stability constraint (7) does not bind (i.e. unconstrained pricing solutions); and those in which it does bind (i.e. constrained pricing).

2.2.1 Unconstrained Pricing Solutions

We start by re-stating a result that was established in Katsoulacos et al. (2015):[16] In every type of industry the overcharge set by a cartel under a simple revenue-based penalty regime is above the monopoly overcharge. Formally we have:

Proposition 1: *For every type of industry,* $\hat{\theta}_R^C > \theta^M$.

Proof: See Appendix 1.

If there were no Competition Authority the cartel would set the monopoly overcharge, which is characterised by marginal revenue equal marginal cost. Faced with an active

[16]One reason for repeating the proposition here is that we offer a new method of proof, which we exploit in our analysis of the pricing properties of a sophisticated revenue-based regime in Proposition 2 below.

Competition Authority, the cartel has an incentive to reduce the expected penalty that it faces: Under a simple revenue-based penalty regime, it does this by trying to reduce revenue. Since, at the monopoly output, marginal revenue is positive, the cartel does this by setting output below the monopoly output and hence setting the cartel overcharge above the monopoly overcharge. The result is intuitively obvious since the simple revenue-based penalty regime is essentially acting like a probabilistic sales tax.[17]

We turn now to a *sophisticated* revenue-based penalty regime under which the penalty rate that is applied to revenue varies with the overcharge according to an increasing function $\rho_{SR}(\theta)$ which is the same across the industries in the class that we are considering. We then have:

Proposition 2: *If the penalty rate function under a sophisticated revenue-based penalty regime satisfies the condition:*

$$\frac{\rho'_{SR}(\theta)}{\rho_{SR}(\theta)} > \frac{1}{\theta(1+\theta)} \quad \forall \theta \geq 0, \tag{11}$$

then in every type of industry $\hat{\theta}^{C}_{SR} < \theta^{M}$.

Proof: See Appendix 1.

The intuition is straightforward: If we have a constant penalty rate then – as was demonstrated in Proposition 1 – a cartel will have powerful incentives to increase the overcharge in order to reduce the penalty base. These incentives to raise the overcharge can be countered if the penalty rate applied to the base increases at a sufficiently high rate with the overcharge. Proposition 2 makes precise just how large the percentage increase in penalty rate has to be to ensure that the cartel overcharge is below the monopoly overcharge. The inequality in (11) emerges by evaluating the first-order condition for the profit-maximising choice of the

[17]We thank the Editor for pointing this out.

overcharge of a cartel that faces a sophisticated revenue-based penalty regime at the monopoly overcharge and requiring that the marginal profits are negative.

Precisely because the right-hand side of (11) does not depend on industry characteristics we can always pick penalty rate functions that are free from industry characteristics and yet – if they satisfy (11) – we can be confident that they have the desirable property of driving the cartel overcharge below the monopoly overcharge in every industry. Of course, infinitely many functions can satisfy condition (11), but in the interests of other criteria of costs of implementation and transparency/certainty we choose the simplest possible functional form: the linear function

$$\rho_{SR}(\theta) = \sigma_{SR}\theta, \quad \sigma_{SR} > 0, \tag{12}$$

which one can easily verify satisfies (11). Here σ_{SR} is the slope of the linear penalty-rate function.

Consequently, in all that follows we will confine attention to *linear* sophisticated revenue-based penalty regimes in which the penalty-rate function is given by (12). Consistent with the assumption made above for the other penalty regime we assume that $\beta\sigma_{SR} < 1$.

2.2.2 Constrained Pricing Solutions

By substituting (3) and (4) into (7) we obtain the cartel stability condition under both penalty regimes, and can consider to what extent this constrains the cartel overcharge.

Under a simple revenue-based penalty regime a cartel sets a price above the monopoly price, in which case the defection profits are just the monopoly profits. But since these are independent of the cartel overcharge, the stability condition does not constrain the cartel overcharge which should then be set so as to maximise $V_R(\theta)$; and so the cartel overcharge will be $\hat{\theta}_R^C$ for all values of $\Delta \in [0,1]$.

Consequently the cartel stability condition is purely a constraint on Δ that takes the form:

$$\Delta \leq \frac{Y(\beta\rho_R)}{Y(0)}, \tag{13}$$

where $Y(z) \equiv \underset{\theta}{MAX}\, \pi(\theta) - zR(\theta)$. By the Envelope Theorem, $Y(z)$ is a strictly decreasing function of z, so the term on the RHS of (13) is: (i) strictly less than 1; and (ii) a strictly decreasing function of $\beta\rho_R$. So the full characterisation of the cartel overcharge under a simple revenue-based penalty regime is illustrated by the dashed line in Figure 1 and is given by

$$\theta_R^c = \hat{\theta}_R^c > \theta^M, \quad 0 \leq \Delta \leq \frac{Y(\beta\rho_R)}{Y(0)} \equiv \bar{\Delta}_R < 1. \tag{14}$$

Under a linear sophisticated revenue-based penalty regime the cartel price is below the monopoly price and so (7) becomes:

$$V(\theta) = \frac{c\theta Q(c(1+\theta)) - \beta\sigma_{SR}\theta c(1+\theta)Q(c(1+\theta))}{\Delta} \geq c\theta Q(c(1+\theta)) = \pi^d(\theta),$$

which implies

$$\theta \leq \frac{(1-\beta\sigma_{SR}) - \Delta}{\beta\sigma_{SR}}. \tag{15}$$

This upper bound on θ is a linear decreasing function of Δ that takes the value zero when $\Delta = 1 - \beta\sigma_{SR} < 1$. There are certainly values of $\Delta \approx 1 - \beta\sigma_{SR}$ for which the upper bound in (15) lies below the unconstrained overcharge $\hat{\theta}_{SR}^C$; consequently the cartel stability condition binds and constrains the overcharge that the cartel can set. The complete characterisation of the value-maximising cartel overcharge under a linear sophisticated revenue-based penalty regime is:

$$\theta_{SR}^C = MIN\left[\hat{\theta}_{SR}^C, \frac{(1-\beta\sigma_{SR}) - \Delta}{\beta\sigma_{SR}}\right], \quad 0 \leq \Delta \leq 1 - \beta\sigma_{SR} \equiv \bar{\Delta}_{SR} < 1. \tag{16}$$

In Figure 1 below we illustrate the value-maximising cartel overcharge under a linear sophisticated revenue-based regime (solid line) in comparison with that under a simple revenue-based regime (dashed line). The kink in the SR function arises at the point where the cartel stability condition binds. From (16) this occurs where $\Delta = 1 - \beta\sigma_{SR}\left(1 + \hat{\theta}_{SR}^{C}\right) < 1 - \beta\sigma_{SR}$.

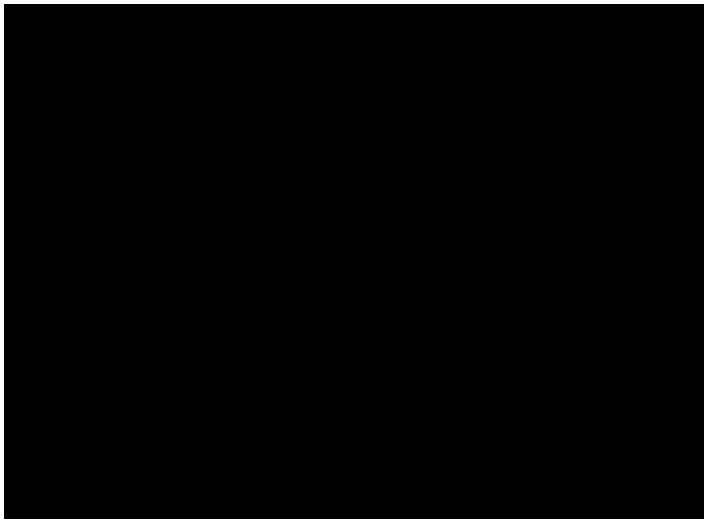

Figure 1: Comparison of the cartel overcharge under a simple revenue-based regime (dashed line), and under a linear sophisticated revenue-based penalty regime (solid line).

2.3 Deterrence

From the analysis in the previous sub-section we see that the maximum critical level of difficulty of holding a cartel together – $\overline{\Delta}_r$ – is determined as a pure upper-bound constraint on Δ in the case of a simple revenue-based regime; while for the linear sophisticated revenue-based regime it is the value at which the constrained overcharge is driven to zero.

From (10), (14), and (16) we see that the degree of deterrence that is achieved by each of the penalty regimes is:

$$D_R = 1 - \frac{Y\left(\beta\rho_R\right)}{Y(0)}; \quad D_{SR} = \beta\sigma_{SR}. \tag{17}$$

To understand better the degree of deterrence that is produced by the simple revenue-based regime in any given industry type, we recall that θ^M is the monopoly overcharge in the given industry type and take a first-order approximation of $Y(\beta\rho_R)$ around zero. This implies the following lemma.

Lemma 3

$$D_R \approx \beta\rho_R\left(1+\frac{1}{\theta^M}\right). \tag{18}$$

Proof: See Appendix 1.

Next, analysis of the degree of deterrence in (17) and (18) above implies the following result:

Proposition 4

(i) *The degree of deterrence that is produced by a simple revenue-based regime varies across industry types in a way that is* ***inversely*** *proportional to the monopoly overcharge in the various industry types.*

(ii) *The degree of deterrence that is achieved by a linear sophisticated revenue-based penalty regime is the same across industry types and is determined solely by* $\beta\sigma_{SR}$.

(iii) *Under both penalty regimes the degree of deterrence is higher the greater are the penalty rate parameters –* ρ_R and σ_{SR} *– respectively.*

Proof: Part (i) of the proposition follows from expression (18). Part (ii) follows from the second expression in (17). Part (iii) follows immediately from (17) and (18).

So, in addition to its poor pricing properties, another disadvantage of the conventional simple revenue-based penalty regime is that – even though the same penalty rate applies across industries – it creates *variable deterrence* across industry types and deters least heavily in those industry types where the monopoly overcharge is greatest, i.e. where the potential harm from having an undeterred cartel is greatest.

Given the results in Propositions 4 (i) and (ii), it is impossible to choose the slope parameter σ_{SR} so that the linear sophisticated revenue-based regime achieves at least as much deterrence as an existing simple revenue-based regime with given penalty rate ρ_R for all industry types. However, suppose that we pick a particular target value for the monopoly overcharge: $\bar{\theta}^M$; then we can certainly claim that if we choose σ_{SR} such that:[18]

$$\sigma_{SR} = \rho_R\left(1+\frac{1}{\bar{\theta}^M}\right), \tag{19}$$

then the linear sophisticated revenue-based penalty regime will achieve the same degree of deterrence as the given simple revenue-based regime for the industry type with the target level of monopoly overcharge, and strictly greater deterrence than the simple revenue-based regime for industry types with an even higher monopoly overcharge.

For example if $\bar{\theta}^M$ was the average monopoly overcharge, then (in terms of deterrence) the linear sophisticated revenue-based penalty regime would do as well as the simple revenue-based regime for the "average" industry – the industry with the average overcharge – and strictly better for all industries with above-average monopoly overcharges.

Then we have the following proposition:

Proposition 5: *In comparison with a given simple revenue-based penalty regime, by suitable choice of slope parameter, a linear sophisticated revenue-based regime can achieve the same degree of deterrence for industry types with a given target level of monopoly overcharge but* ***higher*** *degrees of deterrence in those industry types with higher monopoly overcharges.*

In terms of the degree of deterrence, the linear sophisticated revenue-based regime works better where it matters most. Also note that by changing the target level of monopoly

[18] Eq. (19) is derived by equating D_{SR} to $D_R(\bar{\theta}^M)$ and solving for σ_{SR}, which achieves deterrence equivalence for the target industry type $\bar{\theta}^M$.

overcharge and applying the deterrence equivalence criterion that was described above, one can influence the range of industries for which the linear sophisticated revenue-based penalty regime outperforms the simple revenue-based regime in terms of deterrence.

We can conclude that:

Corollary: *The lower is the target level of monopoly overcharge* $\bar{\theta}^M$ *the steeper will be the slope of the linear sophisticated revenue-based penalty function, but the larger will be the range of industries for which the linear sophisticated revenue-based penalty outperforms the simple revenue-based regime in terms of deterrence*.

To see the potential implications of this for the value of σ_{SR} that is implied by (19) and for the levels of penalties to which it gives rise, we consider the case where $\bar{\theta}^M$ is taken to be the average monopoly overcharge, since that is something that has been extensively studied in the literature. We start from studies of the average cartel overcharge, $\bar{\theta}^C$. A meta-analysis in Connor and Bolotova (2006) suggests a value of $\bar{\theta}^C = 0.31$. On the other hand, a more recent study by Boyer and Kotchoni (2015), which corrects for various biases in Connor and Bolotova (2006), gives figures of 13.6% and 17.5% depending on the sample used. So we set a High estimate of $\bar{\theta}_H^C = 0.3$ and a Low estimate of $\bar{\theta}_L^C = 0.15$. If these are cartel overcharges that emerge from widely used *simple* revenue-based regimes, then – from Proposition 1 – the average monopoly overcharge will be lower.

Let us assume that associated High and Low estimates of this are, respectively $\bar{\theta}_H^M = 0.25$ and $\bar{\theta}_L^M = 0.125$. The typical penalty rate that is used in *simple* revenue-based penalty regimes is $\rho_R = 0.1$. If these figures are plugged into (19), the associated figures for σ_{SR} would be 0.5 and 0.9, respectively.

If we calculate the actual penalty rate that would be charged on cartels that set the average cartel overcharge, then, if the average overcharge was $\bar{\theta}_H^C = 0.3$, the penalty rate that would be

applied to the cartel's revenue under a sophisticated revenue-based penalty regime would be 15%. If instead the average overcharge was $\bar{\theta}_L^C = 0.15$, then – under a sophisticated revenue-based penalty regime – the average cartel would face a penalty rate of 13.5%.

Given the linear nature of our proposed sophisticated revenue-based penalty regime, the penalty rates that would be applied to cartels that set overcharges that were a factor f of the average cartel overcharge – for which $\theta = f\bar{\theta}^C$ – would be just $0.15f$ and $0.135f$, respectively. The penalties that would apply to cartels that set overcharges that were three or four times the average would be around 50% - the sort of figure that has been proposed by Connor and Lande (2008).

In summary, the main conclusion from these calculations is that the precise penalties that would be imposed under the linear sophisticated revenue-based penalty regime that we propose are not very sensitive to the underlying estimate of the monopoly overcharge that is assumed. However penalties do rise quite sharply with the overcharge that is actually set by cartels.

3 Comparison of Regimes in Terms of Implementation Criteria

The two important implementation criteria for assessing penalty regimes are *costs of implementation* and *transparency/certainty*. A simple revenue-based regime performs best on both criteria, since for their calculation they require only the actual cartel revenue.

Sophisticated revenue-based penalties require for their calculation the actual cartel revenue and also estimates of the price overcharge. To the extent that the CA pre-announces the formula for relating the penalty rate to the cartel overcharge the regime is quite transparent. The use of actual cartel revenue as the base means that for this component of the penalty regime it scores just as well as the simple revenue-based regime in terms of our two criteria.

Nevertheless, there are implementation and transparency concerns that arise from the need to calculate the price overcharge. First, what is a reasonable overcharge estimate is debatable – as is reflected in the variation between estimates of defendants and plaintiffs. Second, for a different market setting, where as opposed to our setting cartel agreements may not directly involve prices but instead involve market shares, growth limitations, or geographic limitations, and thus the price consequences are less straightforward, the estimation of the overcharge both in theory and in practice may be substantially more demanding.[19]

However, although there are implementation and transparency concerns that arise from the need to calculate the price overcharge, for the following two reasons we think that these are often exaggerated:[20]

(a) The overcharge that arises in cartel cases has been routinely estimated for many years in private damage claims. These claims have been a very important feature of the North America jurisdictions, have been introduced in EU competition policy since 2014, and are gradually becoming popular in the EU countries too. As is discussed in Brander and Ross (2017), there are now a range of well-tried and well-understood methodologies (of varying degrees of sophistication) for estimating the overcharge: "Overall, we feel that a great deal of progress in damage estimation and related topics has been made in the past two decades. In addition, data availability has significantly improved and computing power has increased

[19] Nevertheless, e.g. Brander and Ross (2017) demonstrate reliable methods for calculation of overcharges in differentiated products setting, such as the methods that were employed in the *Microsoft case* (*Pro-Sys Consultants Ltd. v. Microsoft Corporation*, 2013 SCC 57) and in the *Infineon case* (*Pro-Sys Consultants Ltd. v. Infineon Technologies AG*, 2009 BCCA 503).

[20] Further such concerns apply also to those cases found in practice in which CAs use the overcharge as an "aggravating factor" in setting the penalty rate.

greatly. Therefore, good estimates of damages from price-fixing and related anticompetitive practices can often be obtained".[21]

(b) It is sometimes argued that having to calculate the overcharge imposes an excessive burden on CAs. However, this need not be a cost to the CA. We note that in private damages claims the estimation is undertaken by those claiming damages and the Courts balance their evidence against the counter estimates made by the defendants in reaching their decision. If the sophisticated revenue-based regime is adopted, there is nothing to stop the CAs from requesting that the parties (defendants and plaintiffs) make available their estimates of the price overcharge (with detailed justification) along with the other documents that they are asked to produce during the investigative procedure. In regimes that allow for private damages, the parties will be incurring the costs of providing these estimates anyway. In regimes where private damage suits are not available, the imposition of these costs on the parties is likely to have beneficial welfare effects since it will increase the costs to cartel offenders of being detected while reducing the incentives of plaintiffs to make false claims of law violation.

4 Qualifications and Extensions

4.1 Robustness of Analytical Framework

We have demonstrated our results for a class of industries that are characterised by symmetric firms, homogeneous products, constant unit costs, and Bertrand competition, which implies

[21] See also Brander and Ross (2006).

that: (a) all firms in the industry will be in the cartel;[22] and (b) the but-for price in the absence of collusion is equal to unit cost. However, we recognise that, though widely used, our model is special and that there are a number of important alternatives to explore so as to support the robustness of our results.

In many industries but-for prices will be above unit cost – for example differentiated products industries or industries that are characterised by Cournot behaviour. A full treatment of these is a non-trivial task. Nevertheless, we have undertaken some exploration of robustness and have shown that our key result in (11) that characterises a penalty regime that induces the cartel price to be below the monopoly price goes through if the but-for price – p^B – is above unit cost.

Proposition 6 below shows that the result of Proposition 2 extends to this more general setting.

Proposition 6: *If* $p^B \geq c$ *and the penalty rate function under a sophisticated revenue-based penalty regime satisfies condition* $\frac{\rho'_{SR}(\theta)}{\rho_{SR}(\theta)} > \frac{1}{\theta(1+\theta)} \quad \forall \theta \geq 0$, *then in every type of industry* $p^B \leq \hat{p}^C_{SR} < p^M$.

Proof: See Appendix 2.

Also the comparison of the welfare properties of the sophisticated revenue-based regime and the simple revenue-based regime does not change in these more general settings. The reason is that the cartel price under the simple revenue-based regime is independent of the level

[22] Extending the analysis to an asymmetric setting where not all firms are in the cartel is a non-trivial task, which requires the development of a very different model.

of the but-for price and is always above the simple monopoly price.[23] Combining this with the result of Proposition 6 we can establishes that the conclusions about superior price effects of our proposed sophisticated revenue-based regime carry over to this more general setting, where but-for prices can be above the unit cost.[24]

4.2 Do cartels take account of possible penalties when setting their price?

It is often claimed that cartel pricing decisions may be unaffected by the nature of the future penalties that will be imposed if/when the cartel is successfully prosecuted by a CA. But if one believes in deterrence, it is hard to see why one dimension of behaviour – forming a cartel - is affected by anticipated future penalties but cartel pricing is not.

Our analysis requires that firms take account of how prices affect fines.[25] This can be realized in two ways: One possibility is that firms expect penalties to change when the overcharge changes. Another channel could be that prices affect the probability of detection: Higher overcharges cause more suspicion from CAs, which increases the probability of being caught and, hence, increases the expected fine.[26]

A recent contribution by Gonzalez and Moral (2018) shows empirical support for the first possibility: Cartels *do take account of anti-cartel enforcement in their decision-making* in terms

[23] To verify this see expressions (A.2) in Appendix 1 and (A.5) in Appendix 2, which are obtained by setting up the cartel value functions under simple revenue-based penalty in terms of overcharges or prices and taking the FOC with respect to the overcharge or price, respectively.

[24] At this level of generality without restricting analysis to a specific functional form for the demand structure, it is hard to obtain tractable results with respect to comparisons of the deterrence properties in the environment, where but-for prices are above marginal cost.

[25] A similar approach is taken in e.g. Bageri et al. (2013), Bos et al. (2018), and Houba et al. (2018).

[26] See, e.g., Harrington (2004, 2005) or Houba et al. (2010).

of both pricing decisions and decisions about forming cartels. In their study of the impact of penalties on fuel prices, Gonzalez and Moral (2018) show that "gas stations branded by the sanctioned companies significantly increased prices relative to their non-sanctioned ones", which is consistent with the extensive theoretical evidence cited above that existing penalty regimes induce prices above the monopoly price. The second channel is discussed in, e.g., Harrington (2004, 2005), where firms are concerned about creating suspicions that a cartel has formed. In this case higher prices may also affect the perceived probability of detection and, hence, the expected penalty.

5 Conclusions

We conclude that sophisticated revenue-based penalties in which the penalty rate that is applied to revenue rises linearly with the level of overcharge, according to a pre-announced formula, will welfare-dominate simple revenue-based penalties in terms of both the prices that they induce cartels to set and the levels of deterrence that are achieved. Moreover, as was discussed above, they are relatively easy to implement and do not give rise to any significant transparency/uncertainty concerns. Consequently, linear sophisticated revenue-based penalties deserve to be considered seriously: They can be seen as a regime in which the current practice of some CAs – that consists of taking into account, in a largely *ad hoc* and informal way, a number of "mitigating and aggravating factors" in setting penalty rates – is formalised in a manner that embodies transparency, relative ease of implementation, and superior welfare properties.

Appendix 1: Proofs of Propositions

Proof of Proposition 1: It is a standard result that the monopoly overcharge is the solution to the equation

$$\eta\left[c\left(1+\theta\right)\right]=\frac{1+\theta}{\theta}. \tag{A.1}$$

Insert (3) from the text into the maximand in (8), differentiate, set the derivative to zero, and re-arrange, and we find that $\hat{\theta}_R^C$ is a solution to the equation:

$$\eta\left[c\left(1+\theta\right)\right]=\frac{1-\beta\rho_R}{\frac{\theta}{1+\theta}-\beta\rho_R}\equiv\varphi_R(\theta). \tag{A.2}$$

It is readily verified that the RHS of the equation is a decreasing function of θ, while, from (1) in the text, the term on the LHS is a strictly increasing function of θ. Moreover since

$$\frac{1-\beta\rho_R}{\frac{\theta}{1+\theta}-\beta\rho_R}>\frac{1+\theta}{\theta}, \tag{A.3}$$

Proposition 1 is established. The dashed line in Figure 2 below illustrates the proof.

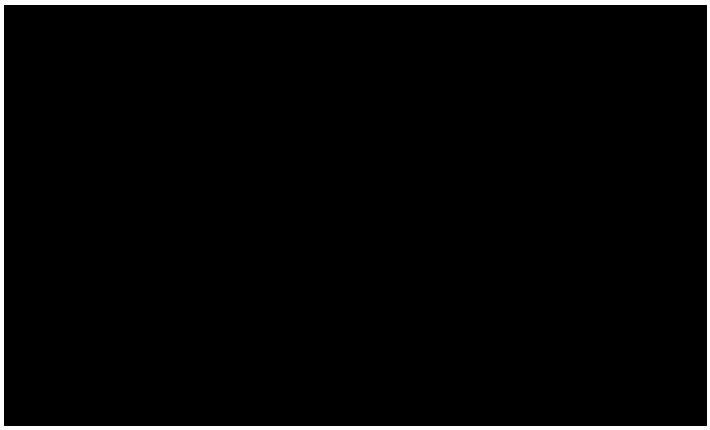

Figure 2: Unconstrained Cartel Overcharges for a Simple Revenue-based Penalty Regime and for a Sophisticated Revenue-based Penalty Regime

Proof of Proposition 2: Insert (4) into the maximand in (8), differentiate, set the derivative to zero and re-arrange and we find that $\hat{\theta}_{SR}^C$ is the solution to the equation:

$$\eta\left(c(1+\theta)\right)=\frac{1-\beta\rho_{SR}(\theta)-\beta(1+\theta)\rho'_{SR}(\theta)}{\frac{\theta}{1+\theta}-\beta\rho_{SR}(\theta)}\equiv\varphi_{SR}(\theta)\,. \qquad \text{(A.4)}$$

Then in order to derive the inequality in (11) we need to find the condition on the function $\rho_{SR}(\theta)$ such that $\varphi_{SR}(\theta)<\frac{1+\theta}{\theta}$. This will reduce the overcharge $\hat{\theta}^{C}_{SR}$ below the simple monopoly level θ^{M}. Note that $\varphi_{SR}(\theta)<\frac{1+\theta}{\theta}$ is equivalent to

$$\frac{1-\beta\rho_{SR}(\theta)-\beta(1+\theta)\rho'_{SR}(\theta)}{\frac{\theta}{1+\theta}-\beta\rho_{SR}(\theta)}<\frac{1+\theta}{\theta}\Leftrightarrow\frac{\rho'_{SR}(\theta)}{\rho_{SR}(\theta)}>\frac{1}{\theta(1+\theta)}\,.$$

The last inequality implies that (11) holds and Proposition 2 is established. Solid line in Figure 2 illustrates the proof.

Proof of Lemma 3: Take a first-order Taylor approximation to $Y\left(\beta\rho_{R0}\right)$ around 0. Then: (i) by the Envelope Theorem $Y'(z)=-R\left(\hat{\theta}(z)\right)$ where $\hat{\theta}(z)$ is the overcharge that maximises $Y\left(z\right)$; and (ii) when $z=0$, $\hat{\theta}(0)=\theta^{M}$ we have

$$Y\left(\beta\rho_{R}\right)\approx Y(0)-\beta\rho_{R}R(\theta^{M})=c\theta^{M}Q\left(c(1+\theta^{M})\right)-\beta\rho_{R}c\left(1+\theta^{M}\right)Q\left(c(1+\theta^{M})\right)\,.$$

$$\text{So } D_{R}=1-\frac{Y\left(\beta\rho_{R}\right)}{Y(0)}=1-\left\{1-\beta\rho_{R}\left[\frac{c(1+\theta^{M})Q\left[c\left(1+\theta^{M}\right)\right]}{c\theta^{M}Q\left[c\left(1+\theta^{M}\right)\right]}\right]\right\}=\beta\rho_{R}\frac{(1+\theta^{M})}{\theta^{M}}\,,$$

which proves the result.

Appendix 2: Proof of Extension

This Appendix extends the result of Proposition 2 to industries in which the but-for prices in the absence of collusion are greater than unit cost. Because the but-for price $p^B \geq c$ is now variable, it is useful to do the analysis directly in terms of price rather than overcharge. In such industries if a cartel forms and sets a price $p > p^B$, then the percentage overcharge is $\theta = \left(p - p^B\right) \Big/ p^B$. Proposition 6 stated in terms of prices shows that the result of Proposition 2 extends to this more general setting.

Proof of Proposition 6: First, it is easy to see that under a simple revenue-based penalty the unconstrained cartel price $\hat{p}_R^C$ is independent of p^B and is given by the solution to:

$$\eta(p) = \frac{p}{p - \dfrac{c}{1 - \beta\rho_R}} \ . \tag{A.5}$$

Note that it is above the simple monopoly price p^M, which is characterized by $\eta(p) = \dfrac{p}{p-c}$.

Under sophisticated revenue-based penalty regime the unconstrained cartel price is solution to:

$$\eta(p) = \frac{p\left[1 - \beta\rho\left(\dfrac{p - p^B}{p^B}\right) - \beta\rho'\left(\dfrac{p - p^B}{p^B}\right)\dfrac{p}{p^B}\right]}{p - c - \beta p\rho\left(\dfrac{p - p^B}{p^B}\right)} \ . \tag{A.6}$$

After some manipulation, it is easy to see that

$$\frac{p\left[1 - \beta\rho\left(\dfrac{p - p^B}{p^B}\right) - \beta\rho'\left(\dfrac{p - p^B}{p^B}\right)\dfrac{p}{p^B}\right]}{p - c - \beta p\rho\left(\dfrac{p - p^B}{p^B}\right)} < \frac{p}{p-c} \Leftrightarrow \frac{c}{p-c} < \frac{\rho'\left(\dfrac{p - p^B}{p^B}\right)\dfrac{p}{p^B}}{\rho\left(\dfrac{p - p^B}{p^B}\right)} \ . \tag{A.7}$$

But if the function $\rho(\theta)$ satisfies our condition (11) $\dfrac{\rho'(\theta)}{\rho(\theta)} > \dfrac{1}{\theta(1+\theta)}$, then it follows that

$$\frac{\rho'\left(\frac{p-p^B}{p^B}\right)\frac{p}{p^B}}{\rho\left(\frac{p-p^B}{p^B}\right)} > \frac{p^B}{p-p^B} \geq \frac{c}{p-c}, \qquad \text{(A.8)}$$

where the last inequality in (A.8) holds for all $p^B \geq c$. The condition (11) that we imposed will guarantee that the unconstrained cartel price is below the monopoly price. Indeed, having a but-for price above marginal cost makes it even more likely to be true.

Acknowledgements For helpful comments we are grateful to John Davies, Peter Dijkstra, Joe Harrington, Fabienne Ilzkowitz, Frederic Jenny, Tom Ross, Maarten-Pieter Schinkel, and participants at the 12th and 13th Annual CRESSE Conference (July 2017 & 2018 respectively) and at the Symposium on "Cartels: Insights on Fines and Enforcement" that was hosted by the Netherlands Authority for Consumers and Markets in the Hague on May 22nd 2018. We also thank the editor and two referees for their very useful comments and suggestions. We are grateful to acknowledge the financial support received through the Tinbergen Institute, Vrije Universiteit Amsterdam, Short-term Visitor Program.

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