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Competitive Pressure and Corporate Crime

Florian Baumann* Tim Friehe†

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Abstract

This paper explores the relationship between the intensity of competition in product markets and firms' incentives to lower their production costs by illegal means. Our framework combines a Salop circle with a crime model à la Becker, allowing us to differentiate between several measures for the intensity of competition. We establish that more firms in the industry (i.e., lower entry costs) reduce the crime rate. Furthermore, whether more intense competition due to the increased substitutability of products raises or lowers the prevalence of criminal behavior can be clearly linked to the impact of such behavior on firms' production costs. Finally, we find that stricter law enforcement may entice more firms to enter the market, despite the higher expected sanction in the event of wrongdoing.

Keywords: product market competition; crime; deterrence; market entry
JEL-Code: K14, K23, L13

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1 Introduction

Since the time of Adam Smith (if not before), economists have recognized the many virtues of competition. However, it has also been argued that competition may be problematic in some respects (see, e.g., Vives 2008). One such claim is that competition may drive firms to engage in unlawful practices; Shleifer (2004, p. 415), for example, argues this point vividly with regard to corruption: "the keener is the competition, the higher is the pressure to reduce costs, and the more pervasive is corruption".[1] The intuition is straightforward and compelling: When some firms engage in unlawful practices and thereby lower their costs, other firms must follow suit or else risk losing market share and potentially being driven out of the market.

This paper analyzes the relationship between the intensity of product market competition and firms' incentives to engage in unlawful practices that reduce production costs. Examples of such practices include the non-adherence to expensive work-place safety regulations and the violation of both minimum wage laws and mandated environmental standards. Real-world examples of minimum wage and other workplace violations in the USA have been presented by Bernhardt et al. (2009), among others.[2] Lowering production costs by means of unlawful practices provides both a direct and an indirect advantage for an individual firm: The direct effect is due to the firm's saving in production costs when all else is held equal, and the indirect effect arises from its improved competitive position. As a result, the incentives for corporate crime are largely determined by the intensity of product market competition. We identify two main effects on firms' incentives for corporate crime that emerge from the intensity of competition; these effects work in opposite directions, such that their relative

[1] A similar argument has been proposed with regard to earnings manipulation (Datta et al. 2013, Bagnoli and Watts 2010) and tax evasion (Goerke and Runkel 2011), among other issues. In addition, although their contribution is not concerned with criminal acts, Hellmann et al. (2000) point out that more intense competition in the banking sector may lead to less prudent risk-taking behavior among bankers.

[2] The recent collapse of a garment factory building in Dhaka, Bangladesh, on April 24, 2013 (see CBCnews, http://www.cbc.ca/news/world/story/2013/05/06/bangladesh-collapse-possible-murder-charges.html), and the illegal dumping of hazardous chemical waste in Yorkshire, Lancashire, and Shropshire (see Environment Agency, http://www.environment-agency.gov.uk/news/138898.aspx?month=4& year=2012& coverage=National& persona=Prosecution) provide further sad evidence that firms indeed make extensive use of such practices.

strength is decisive for the total impact. On the one hand, more intense competition allows a larger gain in market share when a firm reduces its costs by resorting to crime, making crime more attractive. On the other hand, more intense competition lowers overall price-cost margins and makes an increase in market share less profitable, reducing the incentives for crime. In our model, which of these two effects dominates is dependent on the net reduction in production costs implied by crime.

Our paper clearly shows that the relationship between the intensity of competition and firms' incentives to lower costs by engaging in crime may be either positive or negative. This mirrors the sometimes contradictory findings in the literature. Whereas Shleifer (2004), for instance, proposes that fiercer competition aggravates problems associated with corruption, Ades and DiTella (1999) suggest the reverse, i.e., that more intense product market competition may result in a lower incidence of corruption. The setting we use to derive our findings combines the economic model of crime à la Becker (1968) with a model of oligopolistic competition in the vein of Salop (1979). The Salop setup allows us to measure the intensity of competition in two ways: First, the intensity of competition is dependent on the number of firms in the market, and second, consumers' willingness to switch between firms is represented by the transportation cost parameter. Changing this parameter allows us to adjust the intensity of competition by altering a firm's demand elasticity. With free entry, the transportation cost parameter is the primary measure for competitive pressure, other than market entry costs. Our main interest lies in the interactions between product market competition, law enforcement, and corporate crime. We study how the intensity of product market competition affects the prevalence of crime, but also explore the possible repercussions of law enforcement on product market competition.

Our model considers firms that are ex-ante symmetric and learn about the reduction in production costs per unit of output that can be achieved by resorting to an illegal activity. In our framework, the criminal behavior of firms entails social harm, but does not threaten the individual consumer (e.g., because it does not affect product quality).[3] Engaging in

[3]This focus distinguishes our analysis from considerations in which firms deceive consumers in order to increase revenues or offer services to consumers that are deemed unlawful (for the latter, see, for example, Bennett et al. 2013).

the unlawful practice may result in detection and punishment. The sanctions imposed on a criminal firm can be of two types. First, a sanction may be imposed that is proportional to the output produced and therefore proportional to both the extent of criminal behavior and the extent of harm. In addition, a fixed sanction can be levied on the firm in the event of detection. Although this non-linear sentencing structure does not reflect all the details of actual sentencing schemes, we believe that it is in line with the most important aspects of real-world settings. For example, the US Federal Sentencing Guidelines Governing Organizations set out minimum sanctions, resulting in punishments that are not proportional to social harm (see Alexander et al. 1999).[4] We detail how aspects such as the level of sanctions, the possible benefits from crime, and the intensity of product market competition influence whether no, all, or some share of firms chooses to take advantage of the criminal opportunity in equilibrium.

The main findings of our analysis may be summarized as follows. First, more intense competition due to the improved substitutability of products may increase or decrease incentives for crime. As described above, this is the result of two opposing effects that arise from the increase in competition. On the one hand, more intense competition means that firms resorting to crime can realize a larger increase in market share. On the other hand, the lower price-cost margin obtained under more intense competition renders any increase in market share less profitable. The first effect dominates in the event of low to intermediate benefits from crime, while the latter dominates in settings featuring high benefits from crime (i.e., in an environment in which the crime rate is already high). With respect to the number of firms in the industry (i.e., in relation to market entry costs), our framework yields the prediction that more intense competition reduces crime, since a firm's market share decreases relatively more than the total expected sanction it faces. With regard to enforcement policy, we show that stricter law enforcement generally has a deterrent effect. Furthermore, stricter law enforcement can increase expected profits as deterring companies

[4]In addition, Sjoquist (1973) argues that being detected and sanctioned involves two types of costs: quasi-fixed costs and costs that vary with the sanction (which may depend on harm done). In Section 4, we investigate the robustness of our results when the fixed sanction is replaced by a sanction proportional to profits.

from engaging in criminal behavior reduces price competition. However, an increase in the fixed sanction component may also reduce profits (especially when the prevalence of crime is already high) due to its direct negative effect on criminal firms' profits. Consequently, the effect of the fixed sanction on the number of competitors is likely to be non-linear and u-shaped. This interaction between law enforcement and product market competition has a bearing on the optimal law enforcement policy, possibly suggesting another justification for underdeterrence as a means of curbing excessive market entry.

In addition to the contributions mentioned above, the present paper is linked to other research that has investigated corporate crime. Studies on illegal reductions in corporate costs include Danziger (2010) and Basu et al. (2010), who examine minimum wage violations, and Baumann and Friehe (2012), who investigate non-compliance with employment protection legislation. In the realm of environmental economics, a rich literature on law violations focusing on the imperfect enforcement of pollution or technology standards has developed, ranging from Harford (1978) to contributions as recent as Arguedas (2013). However, this research does not touch on our central point of interest, namely the relationship between competition in product markets and corporate crime. Mullin and Snyder (2009) provide a survey on corporate crime; however, they are primarily concerned with principal-agent considerations with regard to the organization of firms and the question of who should optimally be sanctioned (shareholders, the responsible employee, or both). Our paper abstracts from the fact that there must be an individual wrongdoer in the corporation and the important distinction in that context between individual and corporate liability. The contribution closest in focus to ours is Branco and Villas-Boas (2012), who also examine competition and incentives for corporate crime when the latter entails lower production costs. In contrast to our study, Branco and Villas-Boas use a Cournot setup with homogeneous products in their basic model and consider a sanction equal to profits in the event of detection. The two studies can be seen as complements: Our approach allows additional insights, in that product substitutability is introduced as a measure for competitive pressure in addition to the number of firms. Importantly, we investigate different sanction structures, and our baseline model probably more accurately reflects the majority of real-world schemes. In our extensions, we also consider the case in which the sanction is proportional to profits, showing that our findings regarding the relationship between the intensity of competition and firms' incentives to lower costs by illegal means are critically influenced by the assumptions about sanction structure.

Our paper is also related to the literature on process innovations and their interdependence with product market competition, as technically both process innovations and unlawful practices involve a trade-off between something akin to investment costs (represented in our setup by sanctions in the event of detection) and a potential reduction in production costs. Boone (2000) provides a very interesting contribution to the R&D literature in this respect, considering different models of product market competition. Aghion et al. (2005) point to non-monotonicities with regard to the connection between competition and incentives for research investments; similar non-monotonicities arise in our model in the context of the fixed sanction and the number of competitors who enter the market, for example.

The structure of our article is as follows. In Section 2, we describe the model and determine the market equilibrium. We then analyze the effects of the intensity of competition and law enforcement in Section 3. Section 4 offers a discussion of the insights for optimal law enforcement, examines sanctions proportional to profits rather than the fixed sanction, and allows for uncertainty regarding production costs. Finally, in Section 5, we provide concluding remarks.

2 The model

2.1 Description

We consider a market that can be characterized by a Salop-circle of circumference one. Consumers are evenly and continuously distributed along the circle, where the mass of consumers is also normalized to one. Each consumer buys one unit of the good traded in the market. In addition to paying the price for the good, a consumer incurs transportation costs $T \times d$, where d is the distance between the consumer's location and that of the firm where he or she buys the product. Consequently, consumers will choose to buy the product of the firm for which the sum of the price and their transportation costs is the lowest. The number of firms in the market is denoted by n; firms are symmetrically allocated along the circle such that the distance between two firms is always given by $1/n$. In the following analysis, we concentrate on equilibria in which consumers always buy the product of one of the two firms between which they are located. When differences in prices are not too substantial, the demand for a firm i with neighbors $i-1$ and $i+1$ is given by[5]

$$D_i = \frac{1}{n} - \frac{2p_i - p_{i-1} - p_{i+1}}{2T}. \tag{1}$$

Equation (1) clearly indicates the two main elements that determine the intensity of competition in the market. The larger the number of firms n (which, all else equal, results in a lower market share for each firm), the more intense the competition. In addition, the Salop model allows an easily interpretable second factor that characterizes the intensity of competition between firms: the transportation cost parameter T. The lower the value of T, the more flexible consumers become with respect to the decision to switch between firms. Lower values of T thus entail fiercer competition, since even small differences in price can translate into a large shift in demand from one firm to another.

Firms are symmetric and utilize a production technology with constant returns to scale, implying per-unit production costs of c. However, firms may resort to illegal means to reduce their production costs (e.g., illegal waste disposal, violations of minimum wage laws, or reductions in workplace safety) that imply harm h per unit of production for society. A firm that takes advantage of the illegal opportunity reduces its production costs per unit by b, $b < c$. When firms determine whether or not to enter the market, they only know the distribution of the benefit on the interval $[\underline{b}, \overline{b}]$ according to the distribution function $G(b)$, such that the entry decision is not conditional on the realization of the benefit. Illegal behavior by a firm is detected and sanctioned with probability q.[6] We assume that the sanctions consist of two parts: a sanction proportional to output (i.e., proportional to the

[5] After describing the equilibrium at the price-setting stage, we will explain the parameter configurations for which this outcome emerges in equilibrium (see inequality (12)).

[6] We abstract from the possibility of congestion of enforcement resources, which is addressed elsewhere in the literature (see, e.g., Ferrer 2010).

extent of the firm's criminal behavior) and a fixed sanction that is non-proportional to output. The sanction per unit of output is denoted by s; the fixed component of the sanction by F.

The timing of the model is as follows. Firms decide on market entry at stage 0, which determines the number of firms in the market. At stage 1, firms learn the level of cost reduction b associated with illegal production practices. Firms decide whether or not to take advantage of this criminal opportunity at stage 2. This decision cannot be observed by competitors, who must therefore form expectations about the decisions made by their rivals. Next, at stage 3, price setting takes place: All firms simultaneously set their prices and consumers make their purchasing decisions. Finally, random detection occurs and payoffs are realized.

The analysis of the model will start at stage 3, where firms determine their prices based on expectations about the share of firms that has opted for illegal production practices at stage 2. The expected profits of a firm i that does not take advantage of the criminal opportunity (referred to as a firm L in the following analysis) is given by

$$E\pi_i^L = (p_i - c)\left(\frac{1}{n} - \frac{2p_i - Ep_{i-1} - Ep_{i+1}}{2T}\right), \tag{2}$$

that is, profits per unit times expected demand, where E denotes the expectations operator. The expected profits of a firm i that engages in illegal production (a firm C in the following analysis) amount to

$$E\pi_i^C = (p_i - c + \Delta)\left(\frac{1}{n} - \frac{2p_i - Ep_{i-1} - Ep_{i+1}}{2T}\right) - qF, \tag{3}$$

where $\Delta = b - qs$ denotes the firm's expected reduction in marginal costs incorporating the proportional fine in the event of detection. For our analysis, we concentrate on the case of underdeterrence with respect to the variable sanction, at least for high levels of the benefit b, i.e., $\bar{b} > qs$.[7]

[7] In most circumstances, especially when increases in the detection probability are costly, underdeterrence is a feature of the optimal enforcement policy chosen by a benevolent policy maker (see, e.g., Polinsky and Shavell 2007).

2.2 Stage 3: Price competition

Each firm chooses its price level to maximize expected profits, given either by equation (2) or (3). The corresponding first-order condition for a firm L is

$$\frac{\partial E\pi_i^L}{\partial p_i} = \frac{1}{n} - \frac{4p_i - Ep_{i-1} - Ep_{i+1} - 2c}{2T} = 0; \tag{4}$$

in contrast, for a firm C, it is given by

$$\frac{\partial E\pi_i^C}{\partial p_i} = \frac{1}{n} - \frac{4p_i - Ep_{i-1} - Ep_{i+1} - 2c + 2\Delta}{2T} = 0. \tag{5}$$

Introducing the parameter α to denote the expected share of firms of type C, we can express expected prices as

$$Ep_{i-1} = Ep_{i+1} = \alpha p^C + (1-\alpha)p^L \tag{6}$$

where p^C (p^L) denotes the equilibrium price level of a firm C (a firm L). Combining equations (4) through (6), we obtain the equilibrium prices

$$p^L = \frac{T}{n} + c - \frac{\alpha}{2}\Delta \tag{7}$$

and

$$p^C = \frac{T}{n} + c - \frac{1+\alpha}{2}\Delta. \tag{8}$$

For positive net variable gains from crime ($\Delta > 0$), the prices of both a firm L and a firm C decrease in the expected share of firms that use illegal practices to reduce production costs, whereas the price difference remains constant. This results from the fact that the lower production costs of criminal competitors lead to more aggressive pricing, forcing all firms to charge lower prices. Furthermore, the price charged by a firm C is lower than the prices set by law-abiding firms according to the difference in (expected) variable costs; this difference naturally increases in the expected net benefit from crime Δ. In the subsequent analysis, the difference between the price-cost margin of a firm C and that of a firm L proves to be significant. This difference is given by

$$\delta_{pcm} \equiv (p^C - c + \Delta) - (p^L - c) = \frac{\Delta}{2} \tag{9}$$

and is positively dependent on the net benefit from crime.

The price difference established above translates into a corresponding difference in expected demand. The expected demand for the two types of firms can be expressed by

$$ED^L = \frac{1}{n} - \frac{\alpha\Delta}{2T} = \frac{1}{n} - \frac{\alpha}{T}\delta_{pcm} \tag{10}$$

and

$$ED^C = \frac{1}{n} + \frac{(1-\alpha)\Delta}{2T} = \frac{1}{n} + \frac{(1-\alpha)}{T}\delta_{pcm}, \tag{11}$$

respectively, where we assume that demand is positive for a law-abiding firm, even when $\alpha = 1$. A sufficient condition for this to result is

$$\frac{T}{n} > \frac{\bar{b} - qs}{2} \tag{12}$$

which we assume is fulfilled in equilibrium.[8] As with prices, the difference in expected demand between a firm L and a firm C depends on the net benefit obtained from crime and the level of transportation costs

$$\delta_D \equiv ED^C - ED^L = \frac{\Delta}{2T} = \frac{\delta_{pcm}}{T}. \tag{13}$$

Finally, we obtain the expected profits of a firm L and a firm C:

$$E\pi^L = T\left(\frac{1}{n} - \frac{\alpha\Delta}{2T}\right)^2 \tag{14}$$

and

$$E\pi^C = T\left(\frac{1}{n} + \frac{(1-\alpha)\Delta}{2T}\right)^2 - qF. \tag{15}$$

Since equilibrium prices decrease in the share of firms of type C, the expected profits of firms of both types (L and C) decrease in α. This completes the description of the price setting stage.

[8]It must be noted that inequality (12) is not a simple parameter constraint when we consider endogenous market entry.

2.3 Stage 2: Decision on crime

At stage 2, after having learned the actual level of b, each firm decides whether or not to take advantage of the illegal opportunity to reduce its costs. The unlawful practice reduces production costs per unit by b but, also entails costly expected punishment. Since profit levels depend on the decisions made by other firms with respect to crime (as established in equations (14) and (15) above), at stage 2 of the game we are looking for a Nash equilibrium; here, we restrict our focus to the symmetric equilibrium. That is, the equilibrium value of α (the share of competitors engaging in illegal practices) must in equilibrium coincide with the probability that a firm will choose to violate the law. Note that the absolute decrease in profits induced by an increase in α is more pronounced for a firm C, due to the fact that the decrease in its profit margin is experienced for a larger output in comparison to a firm L. Accordingly, the equilibrium value of α to be established will be unique for a given level of the net variable benefit from crime Δ. As long as the criminal opportunity allows higher expected profits, additional firms will take advantage of it; ultimately, either the profit difference will vanish or all firms will become criminal. At the same time, the profits of a firm C (L) will be strictly increasing (decreasing) in the level of Δ, which argues for a positive relationship between α and Δ: the higher the net variable benefit from crime, the higher its prevalence.

Formally, we obtain the equilibrium level for α, α^*, from

$$\alpha^* \left\{ \begin{array}{c} = 0 \\ \in [0,1] \\ = 1 \end{array} \right\} \text{ for } E\pi^C(\alpha^*) \left\{ \begin{array}{c} < \\ = \\ > \end{array} \right\} E\pi^L(\alpha^*) \tag{16}$$

as

$$\alpha^* = \left\{ \begin{array}{c} 0 \\ \frac{1}{2} + \frac{2T}{\Delta}\left(\frac{1}{n} - \frac{qF}{\Delta}\right) \\ 1 \end{array} \right\} \text{ for } \Delta \left\{ \begin{array}{c} < \Delta^{k1} \\ \in [\Delta^{k1}, \Delta^{k2}] \\ > \Delta^{k2} \end{array} \right\}, \tag{17}$$

where the two critical net benefit levels are given by

$$\Delta^{k1} = \frac{2}{n}\left(\sqrt{T^2 + qFn^2T} - T\right) \tag{18}$$

and

$$\Delta^{k2} = \frac{2}{n}\left(T - \sqrt{T^2 - qFn^2T}\right). \tag{19}$$

It is easy to verify that $\Delta^{k2} \geq \Delta^{k1}$ for $F \geq 0$.

For low values of the net benefits from crime, none of the firms has an incentive to employ the illegal means in order to reduce its production costs. Although the first firm to violate the law realizes the largest level of expected demand should no other firm follow suit, the potential net gain from crime is not high enough to offset the expected fixed sanction. In contrast, for intermediate values of the net benefit from crime, some firms will take advantage of the illegal opportunity. However, the higher the share of firms of type C, the lower the realized level of expected demand becomes; at some point, the realized benefits from crime will no longer be sufficient to compensate for the expected sanction. Firms will opt to engage in illegal practices until the profits of a firm L and a firm C coincide. In the extreme case, the net variable benefit from crime might be so high that even if all firms engaged in the criminal opportunity, their profits would still be higher than the profits of law-abiding firms. In such a setting, an all-crime equilibrium is obtained.

The resulting expected profit levels, which are the same across firms (since $E\pi^C(\alpha^*) = E\pi^L(\alpha^*)$ for $\Delta \in [\Delta^{k1}, \Delta^{k2}]$), are derived by substituting α^* into the respective profit functions established in equations (14) and (15):

$$E\pi(\Delta) = \left\{ \begin{array}{c} \frac{T}{n^2} \\ T\left(\frac{qF}{\Delta} - \frac{\Delta}{4T}\right)^2 \\ \frac{T}{n^2} - qF \end{array} \right\} \text{ for } \Delta \left\{ \begin{array}{c} < \Delta^{k1} \\ \in [\Delta^{k1}, \Delta^{k2}] \\ > \Delta^{k2} \end{array} \right\}. \tag{20}$$

Note that, since expected profits decrease in the share of firms of type C (which itself increases in Δ), equilibrium expected profits are weakly decreasing in the net benefit from crime. In the symmetric equilibrium, the incentives for an individual firm to engage in crime always results in lower expected profits for all firms due to the fact that these incentives also apply to a firm's competitors, with negative effects for each firm involved.

2.4 Stage 0: Market entry

The market entry decisions made by firms at stage 0 are guided by a comparison of ex-ante expected profits and market entry costs denoted by K. At stage 0, firms do not yet know the realization of the benefits obtainable from illegal behavior, but only the respective cumulative distribution function denoted by $G(b)$, where b is distributed on $[\underline{b}, \overline{b}]$. Ex-ante expected profits Π are a decreasing function of the number of firms in the market, as illustrated by equation (20). Consequently, the number of firms in the market is established as the highest integer number n for which it holds that

$$\Pi = \int_{\underline{b}}^{\overline{b}} E\pi(b - qs)dG(b) \geq K \tag{21}$$

or

$$\Pi = G(\Delta^{k1}+qs)\frac{T}{n^2}+\int_{\Delta^{k1}+qs}^{\Delta^{k2}+qs} T\left(\frac{qF}{\Delta} - \frac{\Delta}{4T}\right)^2 dG(\Delta+qs)+\left(1 - G(\Delta^{k2} + qs)\right)\left(\frac{T}{n^2} - qF\right) \geq K. \tag{22}$$

This completes the description of the model. We now turn to the comparative-static analysis, in which we will focus on the effects of the intensity of competition on the prevalence of crime and the effects of the enforcement parameters.

3 Analysis

In order to present the economic intuition of the results more comprehensible, we subdivide this section into two parts. First, we disregard the market entry decision; that is, we investigate the subgame starting at stage 1. In a second step, we complete our analysis by allowing for the endogenous determination of the number of firms in the market.

3.1 Given number of firms n

Our primary interest in this section is determining how the intensity of competition (Section 3.1.1) and law enforcement (Section 3.1.2) affect the prevalence of crime. According to the description of our model set out above, an increase in the intensity of competition results from either an increase in the number of firms in the market or lower transportation costs (and the corresponding higher consumer flexibility). In addressing the resultant influence on the extent of crime in equilibrium, we focus on the share of firms engaging in criminal acts α^* and the corresponding critical net benefit levels Δ^{k1} and Δ^{k2}. Note that the share of firms α^* is highly indicative of the extent of crime, given that there is fixed overall demand of one in the Salop framework. Furthermore, with regard to law enforcement, we will evaluate the resulting changes in expected profits in the market; this will determine the effects on market entry investigated in the next section.

3.1.1 Intensity of competition

We start by investigating an exogenous increase in the number of competitors n. The results are summarized by:

Proposition 1 *An increase in the intensity of competition induced by a higher number of competitors reduces the prevalence of crime in equilibrium, i.e., the share of criminal firms* α^* *(weakly) decreases with a corresponding upward adjustment in the two critical net benefit levels* Δ^{k1} *and* Δ^{k2}.

Proof. The proof follows from equations (17), (18), and (19). For details, see Appendix A. ■

The intuition for this first result can be explained in the following fashion. When all else is held equal, an increase in the number of firms in the market reduces the market share for each firm by the same absolute amount (as is evident from the equilibrium demand equations (10) and (11)). However, due to the higher absolute price-cost margin for a firm C (see equation (9)), the corresponding reduction in profit is less pronounced for a firm L. Consequently, for $\alpha^* \in (0, 1)$, the share of criminal firms is adjusted downwards; as a result, the minimum net benefit level required for an all-crime equilibrium is now higher, and the critical benefit level below which a no-crime equilibrium results increases as well. All in all, for a positive fixed sanction F, more intense competition in the form of an increase in the number of competitors makes crime less attractive.[9]

We now turn to the effect of a change in transportation costs. The results are summarized in:

[9] For $F = 0$, all (none) of the firms will choose to take advantage of the illegal opportunity for $\Delta > (<) 0$, which in this case only depends on a comparison between benefits b and the variable sanction qs. For $F = 0$, the number of firms does not affect the incentives for crime.

Proposition 2 *An increase in the intensity of competition induced by a decrease in transportation costs T (weakly) increases α^* when $\Delta < nqF$ and (weakly) decreases α^* when $\Delta > nqF$. Correspondingly, the lower critical value for the net benefit Δ^{k1} decreases, whereas the higher critical value Δ^{k2} increases.*

Proof. The proof follows again from equations (17), (18), and (19). For details, see Appendix B. ■

A decrease in transportation costs makes consumers more willing to switch to another firm, and price competition between firms becomes fiercer as a result. The price-cost margin of a firm L and a firm C decreases by the same absolute amount (i.e., the difference between the two types of firms remains unaffected; see equation (9)). However, this effect has a stronger negative impact on the expected profits of a firm C, due to its higher market share in comparison to a firm L. This suggests that corporate crime should be rarer in settings with a lower T. However, at the same time, the extension of market share obtained by resorting to illegal means of reducing costs increases due to higher consumer flexibility (see equation (13)). This effect leads to an increase in the expected profits of a firm C in comparison to those of a law-abiding competitor.

In equilibrium, the sign of the combined effects is ambiguous; as Proposition 2 indicates, it depends on the net benefit per unit obtained from crime. For a relatively low value of the net benefit from crime, the difference in market shares between a firm C and a firm L is small, and therefore the first effect described above (i.e., lower price-cost margins) is less significant in the comparison of profit levels. The second effect dominates, crime becomes more favorable for a given share of criminal firms, and the share of criminal firms (weakly) increases. In contrast, for a relatively large net benefit from crime, the initial difference in market shares is more pronounced, and the first effect dominates the second, such that the expected profits of firm C decrease relative to those of a firm L for a given α. Consequently, the share of criminal firms (weakly) decreases in this case.

Since the level of the net benefit from crime has a direct bearing on the share of firms taking advantage of the criminal opportunity, we can explain our findings in another way. By reference to equation (17), it is easily established that $\alpha^* < (>)1/2$ for $\Delta < (>)nqF$.

Consequently, for an initial equilibrium with a low crime rate ($\alpha^* < 1/2$), fiercer competition due to a decrease in transportation costs leads to the intuitive result that more intense competition increases the incentives for corporate malfeasance. However, we establish that this result cannot be generalized. If the initial market equilibrium is characterized by a relatively high crime rate ($\alpha^* > 1/2$), an increase in the intensity of competition reduces incentives for crime. Criminal behavior permits an increase in market share; however, the additional profits obtained by this increase are less valuable due to the lower price-cost margin resulting from more intense competition.

Finally, it should be noted that the inclusion of a criminal opportunity in the analysis does not affect the standard prediction that fiercer competition due to lower transportation costs reduces expected profits in equilibrium.[10]

3.1.2 Law enforcement

The parameters at the disposal of a law enforcement agency are represented by the probability of detection q and the two sanction levels s and F.

Proposition 3 *Stricter law enforcement enacted by means of an increase in the variable sanction s, the fixed sanction F, or the detection probability q reduces corporate crime.*

Proof. With regard to the fixed sanction F, the result can be established by examination of equations (17) to (19). For $\alpha^* \in (0,1)$, the share of criminal firms decreases in F. The two critical benefit levels Δ^{k1} and Δ^{k2} are both increasing in F. The effect of an increase in the variable sanction s can most easily be established by referring to the expected profits of a criminal firm and a law-abiding firm for a given share of criminal firms, equations (14) and (15). Given α, the former decrease while the latter increase in s (i.e., a decrease in Δ); this would necessitate a decrease in α to equalize profit levels in the event of $\alpha^* \in (0,1)$. The effect of an increase in q is similar to a proportional increase in both s and F. ■

The effects of law enforcement are standard for a given number of firms. Nevertheless, let us briefly outline the mechanism behind the adjustments. First, consider an increase in the

[10]This statement follows from equation (20).

variable sanction s. Such an increase is tantamount to a reduction in the net benefit from crime Δ and has a direct negative effect on the expected profits of a firm C. In addition, for a given share of criminal firms a reduction in the net benefit from crime reduces the gap in the price-cost margin (see equation (9)), and therefore the expected market share of a firm C decreases while that of a firm L expands. To summarize, we find that the expected profits of a firm C decrease whereas the expected profits of a firm L rise, such that the share of criminal firms will be (weakly) lower after an increase in the sanction: The prevalence of crime is reduced. In comparison, an increase in the fixed sanction F has no direct bearing on price-cost margins or the market shares of firms. In this case, only the direct effect of a higher expected sanction is in play, but this nevertheless reduces the incentives for crime. Finally, the effects of an increase in the detection probability q are similar to a proportional increase in the two sanction levels.

Finally, in preparation for the analysis of a setting with endogenous market entry, we report the effect of law enforcement on expected profits.

Proposition 4 *An increase in the variable sanction s increases expected profits in equilibrium when $\Delta \in [\Delta^{k1}, \Delta^{k2}]$; otherwise, such an increase leaves profits unchanged. An increase in the fixed sanction F leaves expected profits unchanged when $\Delta < \Delta^{k1}$, increases expected profits when $\Delta \in \left(\Delta^{k1}, \Delta^{k2}\right)$, and reduces expected profits when $\Delta > \Delta^{k2}$. An increase in the detection probability q corresponds to a proportional increase in both s and F.*

Proof. The proof follows from equation (20). Note that any marginal change in the two critical net benefit levels Δ^{k1} and Δ^{k2} has no direct bearing on expected profits, due to the endogenous decision made by firms regarding their participation in crime. ■

Stricter law enforcement affects expected profits through two different channels. First, there is the direct effect whereby higher expected sanctions reduce the expected profits of a firm C while leaving the expected profits of a firm L unchanged. Second, as previously established, the resulting change in the difference in profits between the two types of firms results in a weakly lower share of firms of type C in equilibrium, which increases the expected profits of both a firm L and a firm C. Because these two profit levels are equalized in an equilibrium with $\alpha^* \in (0,1)$, expected profits necessarily increase in this range. Consequently, for intermediate values of the net benefit from crime (where $\alpha^* \in (0,1)$ holds), stricter law enforcement unambiguously increases expected profits.

When the net benefits from crime exceed the threshold Δ^{k2}, an all-crime equilibrium is obtained. All firms are now impacted by the direct effect of an increase in the expected fine. However, the variable sanction s and the fixed sanction F now differ in that only the variable sanction implies an additional indirect effect on profits. This indirect effect stems from the fact that the marginal costs of production (including the net benefits from crime) increase, with the result that price competition in the market becomes less fierce. As can be easily deduced from equation (20), the direct and indirect effects of an increase in the variable sanction s cancel out in an all-crime equilibrium. The fixed sanction, in contrast, has no additional bearing on expected profits, such that only its direct effect applies.

In summary, we determine that an increase in the variable sanction always yields (weakly) higher expected profits in equilibrium. For the fixed sanction, this is only the case for intermediate levels of the net benefit from crime, whereas the opposite applies in the event of an all-crime equilibrium. The effect of an increase in the detection probability is again equivalent to a proportional increase in both sanction levels.

3.2 Endogenous number of firms

In this section, we consider the comparative-statics properties of the full model, taking into account the fact that the number of market participants is determined by the market entry condition, equation (22). As well as the direct effects of more intense product market competition and stricter law enforcement on the prevalence of crime, we now include additional indirect effects. These indirect effects stem from the impact of changes either in law enforcement or in the intensity of product market competition on equilibrium profits and thereby on the market entry decision (which in turn has repercussions on the extent of crime in equilibrium). This can be expressed by restating the equilibrium share of firms of type C as

$$\alpha = \alpha(T, s, F, q, n(T, s, F, q)), \tag{23}$$

to highlight the direct and indirect effects.

3.2.1 Intensity of competition

In the full model, where the number of firms is determined endogenously, the remaining parameter indicating the intensity of competition is the transportation cost parameter T. An additional parameter that could be considered here is the market entry cost K. Lower market entry costs indicate easier market access and will increase the intensity of competition, as more firms will enter the market. The effects on crime are those described in the previous section for an increase in the number of market participants n (see Proposition 1).

Proposition 5 *With endogenous market entry, an increase in the intensity of competition induced by a decrease in transportation costs T implies an ambiguous effect on the prevalence of crime. For $\Delta \leq nqF$ before the variation in T, crime prevalence weakly increases; for $\Delta > nqF$ before the variation in T, crime prevalence may decrease, especially for high values of Δ.*

Proof. The proof follows from Propositions 1 and 2 in combination with equation (22), which implies a positive effect of T on n. ■

As before, the total effect of a change in the substitutability of products has an ambiguous effect on the prevalence of crime and depends on the level of the net benefit from crime. As delineated above, the direct effect of more intense product market competition for intermediate levels of net benefit is an increase in the incentives for crime, but a reduction in incentives is found for settings featuring high net benefits. In addition, an indirect effect arises due to the fact that more intense product market competition leads to lower expected profits, which reduces the number of competitors in the market. The accompanying increase in market share for the remaining firms implies higher expected gains from crime as long as the net benefit from crime is positive. Consequently, the effect of more intense product market competition is tilted towards a higher prevalence of crime in equilibrium. However, this indirect effect might not be sufficient to offset the direct effect when there are high net benefits from crime.

3.2.2 Law enforcement

In the following analysis, we concentrate on the effects of an increase in either the variable sanction s or the fixed sanction F, since the effects of a higher detection probability can be understood as a proportional increase in the two sanction levels. To this end, we briefly touch on the relationship between sanction levels and market entry before discussing the overall effect on crime prevalence.

Lemma 1 *An increase in the variable sanction s leads to an (weak) increase in the number of market participants n. An increase in the fixed sanction F may decrease or increase n. For positive net benefits from crime, the introduction of a fixed sanction (weakly) reduces the number of firms. The number of firms is (weakly) lower for $F > 0$ than for $F = 0$ until F reaches a level at which crime is completely eradicated. In this case, the number of market participants is the same as when $F = 0$.*

Proof. For the variable sanction, the proof follows directly from Proposition 4 in combination with the market entry condition, equation (22). For the fixed sanction, consider equations (20) and (22). For $F = 0$, the two critical values Δ^{k1} and Δ^{k2} are equal to zero, such that an all-crime (no-crime) equilibrium results for $\Delta > 0$ ($\Delta < 0$), with expected profits equal to T/n^2 for all values of Δ. The number of firms is therefore given by $n = \sqrt{T/K}$. An increase in F lowers expected profits, and the number of firms in equilibrium (weakly) decreases, without initially changing the all-crime nature of the equilibrium (when $\Delta > 0$). For intermediate values of F, profits may increase or decrease in response to an increase in F, but n is always weakly less than $\sqrt{T/K}$. Finally, for high levels of F (that is, when $\Delta < \Delta^{k1}$ holds for all b due to the high expected fine), profits are again equal to T/n^2 for all values of Δ, and the equilibrium is always a no-crime outcome. ■

As shown in Section 3.1.2, an increase in the variable sanction s always leads to an increase in firms' profit levels in equilibrium due to the deterrence of competitors and the tamer price competition by firms of type C. Accordingly, an increase in the variable sanction will be accompanied by an increase in the number of firms. With regard to an increase in the fixed sanction F, firms again benefit from increased deterrence of competitors but are directly negatively impacted by the higher expected fine in the event of an all-crime equilibrium. For originally low levels of sanctions, the all-crime equilibrium is likely to emerge and the negative effect on expected profits dominates. In contrast, for high sanction levels, the deterrence effect dominates and expected profits increase. In summary, the number of firms in the industry is expected to decrease in response to an increase in F when F is small; however, there is a critical value of F for which a further increase in the fixed sanction entails an increase in the number of firms. Therefore, the relationship between the fixed sanction and the number of market participants is expected to be u-shaped.

We now turn to the effects of law enforcement on crime prevalence, which can be summarized in the following proposition:

Proposition 6 *The deterrent effect of an increase in the variable sanction s is greater when the number of firms is endogenous in comparison to a scenario with an exogenous number of market participants. An increase in the fixed sanction F generally decreases the prevalence of crime; however, for a marginal increase in the sanction F that results in one less firm entering the market, crime can become more prevalent, as the indirect effect of a lower number of competitors can dominate the (marginal) effect on deterrence.*

Proof. The statements follow from Propositions 1 and 4 in combination with Lemma 1. ■

For a change in the level of the variable sanction, we find that both the direct and the indirect effect point in the same direction with regard to the impact on crime. Crime becomes less attractive as a direct result of the higher sanction (see the discussion in Section 3.1.2); in addition, the accompanying increase in the number of firms in the market equilibrium reduces individual market shares, diminishing the benefits from crime even further. For the fixed sanction, it is clear that all firms resort to crime when $F = 0$ and $\Delta > 0$. In contrast, crime is eradicated for (very) high levels of F. Consequently, higher fixed sanctions generally reduce crime. However, the indirect effect on crime suggests that crime increases as the number of firms decreases in the fixed sanction at least for some range of small F. Since the number of firms is an integer, we may find that for certain parameter constellations, a marginal increase in F discretely reduces n and that the direct effect is dominated by the indirect effect, such that crime increases. In contrast, if an increase in the fixed sanction leads to a higher number of firms in equilibrium (which is especially likely when the sanction is high at the outset), the direct deterrence effect will be amplified by the indirect effect due to the change in the number of firms.

4 Discussion and extensions

In this section, we first complement the positive analysis presented above by discussing potential implications for optimal law enforcement policy. We then report the results for two variations in our assumptions. The first variation concerns the sanction structure: We replace the fixed sanction F with a sanction proportional to firm profits in order to test the sensitivity of our results to the sanction structure. The second change in assumptions addresses the uncertainty about firms' production costs, a relevant factor in real-life settings.

4.1 Welfare considerations

The central feature of our framework is that it links behavior in the product market and decisions concerning illegal activities. Our results indicate that law enforcement policy also influences product market outcomes, a finding that should be considered in enforcement policy. This section examines how this impact on the product market affects optimal law enforcement policy in comparison to the standard trade-off described by Polinsky and Shavell (2007), among others.

As an inverse measure of social welfare, we use the sum of social costs resulting from production, including social harm resulting from law violations and the costs of law enforcement. This would seem to be a plausible measure, since the implicit assumption that all consumers buy one unit of the product implies that consumers' gross utility from consumption is independent of the market equilibrium, such that the sum of payoffs is maximized for minimized costs. For a given level of gross benefit from crime b, total expected social costs amount to

$$SC = c - b\alpha nED^C + h\alpha nED^C + ETC + nK + \phi(q, s, F). \tag{24}$$

The first two terms represent the variable costs of production, where the output of the αn firms of type C is produced at reduced costs. This implies social harm h per unit of output. ETC denotes the expected transportation costs borne by consumers, which will be determined below. In addition, social costs comprise market entry costs nK and the costs of law enforcement, where $\partial\phi/\partial x > 0$, $x = q, s, F$. The expected transportation costs for the consumers buying from a firm of type j are given by average expected distance $(ED^j/4)$ times the number of consumers (ED^j) and the transportation costs parameter T. Using equations (10) and (11), we calculate total expected transportation costs as

$$ETC = \frac{T}{4}\left[\alpha n(ED^C)^2 + (1-\alpha)n(ED^L)^2\right] = \frac{T}{4n} + \alpha(1-\alpha)\frac{n\Delta^2}{16T}. \tag{25}$$

that is, for a given number of firms, expected transportation costs are minimal when either $\alpha = 0$ or $\alpha = 1$. In contrast, when some firms take advantage of the illegal opportunity to reduce their production costs while others do not, the resulting price differential implies an increase in overall expected transportation costs, which are maximal for $\alpha = 1/2$. Inserting equations (10), (11), and (25) into equation (24), we obtain

$$SC = c + (h-b)\alpha\left(1 + \frac{(1-\alpha)\Delta n}{2T}\right) + \frac{T}{4n} + \alpha(1-\alpha)\frac{n\Delta^2}{16T} + nK + \phi(q, s, F). \tag{26}$$

As long as stricter law enforcement increases deterrence (i.e., reduces the share or output of firms C), the standard comparison between the reduced net harm from crime $(h-b)$ and the additional enforcement costs arises. The two new elements to be considered are the effects of law enforcement on the expected transportation costs and on the number of firms in the market (and therefore market entry costs nK). As we known, the standard Salop setup implies excessive product differentiation, that is, excessive market entry by firms (see, e.g., Tirole 1988). Consequently, a law enforcement regime that reduces expected profits for a given number of firms and thereby the number of firms in equilibrium can have an additional beneficial effect in terms of total expected social costs.

Against the background of the discussion presented in Sections 3.1.2 and 3.2.2, these additional considerations affecting social welfare primarily concern the optimal combination of the two sanctions s and F. When $F = 0$, the two critical net benefit levels Δ^{k1} and

Δ^{k2} coincide and only no-crime and all-crime equilibria exist. In this case, consumers' transportation costs are minimal but excessive market entry occurs, as is standard in the Salop model. A higher variable sanction increases deterrence and reduces net social harm. When the fixed sanction F is introduced, the law enforcer faces an additional trade-off. First, for some range of F, expected profits decrease, reducing the excessiveness of market entry. At the same time, the use of the sanction F drives a wedge between the two critical net benefit levels Δ^{k1} and Δ^{k2}, implying an increase in expected transportation costs for some range of criminal benefits b. In this case, an increase in the variable sanction s is also accompanied by an increase in expected profits, which invites more market entry. To summarize, because the negative effect on transportation costs is close to zero for low levels of F, the social optimum is likely to feature a positive level for the fixed sanction and may involve a combination of the variable and fixed sanctions. Furthermore, for a positive fixed sanction, the very existence of crime reduces expected profits; this provides an additional argument for underdeterrence to feature in the social optimum, adding to the standard argument about the marginal costs of law enforcement.

4.2 Variation in sanction structure

This section examines how a change in the sanction structure – replacing the fixed sanction F with a sanction proportional to profits – alters the outcomes of our model. We find that some of our results are sensitive to the assumed sanction structure. With a fine proportional to profits, both an increase in consumer flexibility (i.e., a decrease in transportation costs T) and a higher number of competitors result in higher incentives for crime. This has important implications for law enforcement.

When the fixed sanction F is replaced by a sanction proportional to profits, where f, $0 \leq f \leq 1$, denotes the percentage share of profits extracted as a fine, the expected profits for a firm C amount to

$$E\pi^C = (1 - qf)T \left(\frac{1}{n} + \frac{(1-\alpha)\Delta}{2T} \right)^2, \tag{27}$$

whereas the expected profits of a firm L are still given by equation (14). As before, two critical values for the variable net benefit from crime can be established: $\alpha = 0$ constitutes an equilibrium for $\Delta \leq \Delta^{k1}$, and $\alpha = 1$ is an equilibrium for $\Delta \geq \Delta^{k2}$, where

$$\Delta^{k1} = \frac{2T}{n} \frac{1 - \sqrt{1 - qf}}{\sqrt{1 - qf}} \tag{28}$$

and

$$\Delta^{k2} = \frac{2T}{n} \left(1 - \sqrt{1 - qf} \right). \tag{29}$$

Note that $\Delta^{k1} \geq \Delta^{k2}$, such that two symmetric pure strategy Nash equilibria exist for $\Delta \in (\Delta^{k2}, \Delta^{k1})$. In addition, in this parameter range, a symmetric mixed-strategy equilibrium exists. For the following analysis, we assume that the payoff-dominant equilibrium is realized for $\Delta \in (\Delta^{k2}, \Delta^{k1})$, which is the $\alpha = 0$ setting. Accordingly, we obtain

$$\alpha^* = \left\{ \begin{array}{c} 0 \\ 1 \end{array} \right\} \text{ for } \Delta \left\{ \begin{array}{c} \leq \\ > \end{array} \right\} \Delta^{k1}, \tag{30}$$

which implies expected profits of

$$E\pi(\Delta) = \left\{ \begin{array}{c} \frac{T}{n^2} \\ (1 - qf)\frac{T}{n^2} \end{array} \right\} \text{ for } \Delta \left\{ \begin{array}{c} \leq \\ > \end{array} \right\} \Delta^{k1}. \tag{31}$$

Finally, the market entry decision is guided by

$$\Pi = \frac{T}{n^2} \left(1 - qf \left[1 - G(\Delta^{k1} + qs) \right] \right) = K. \tag{32}$$

We begin our comparative-statics analysis by first considering the subgame beginning at stage 1.

Proposition 7 *For a given number of firms and sanctions proportional to output and profits, more intense product market competition induced by either a decrease in transportation costs or an increase in the number of firms increases the expected crime rate by reducing the critical value Δ^{k1} for an all-crime equilibrium. Stricter law enforcement induced by an increase in s, f, or q reduces the expected crime rate by increasing the critical gross value $\Delta^{k1} + qs$ for an all-crime equilibrium.*

Proof. Follows from equations (28) and (30). ■

In contrast to the setting considered in the main part of the paper, more intense competition in the product market now always increases the incentives for criminal behavior. This result can be explained by the additional mechanism that was absent in the scenario with the fixed sanction F. This additional effect stems from the fact that an increase in the intensity of product market competition reduces expected profits in equilibrium. If the sanction imposed on the firm is proportional to this profit level, this implies that expected sanctions decrease while the effects on benefits from crime remain unchanged. It is this decline in expected sanctions that is responsible for the unambiguous increase in the expected crime rate in this setting.

Turning to our comparative-statics analysis with an endogenous number of firms, note first that an increase in f has an ambiguous effect on a firm's expected profits, which are decisive for the entry decision. Although the higher sanction reduces profits in an all-crime equilibrium, it makes the occurrence of such an equilibrium less likely (which increases ex-ante expected profits). Again, the gigher the expected crime rate, the more pronounced the negative effect on profits; the effect of f is likely to be non-linear and may even change sign for some positive level of f. The sanction s increases expected profits due to its deterrent effect; in this case, this effect is beneficial for firms in this case, since profits in a no-crime equilibrium are strictly larger than those in an all-crime equilibrium for $f > 0$. Again, an increase in the detection probability is analytically similar to a proportional increase in both s and f. The overall effects of the intensity of competition and law enforcement in equilibrium can be described thus:

Proposition 8 *With endogenous market entry and sanctions proportional to output and profits, more intense product market competition (i.e., a decrease in transportation costs T) increases the expected crime rate by reducing the critical value Δ^{k1} for an all-crime equilibrium. Stricter law enforcement (i.e., an increase in s, f, or q) reduces the expected crime rate.*

Proof. Follows from equations (28) and (30) to (32). For details, see Appendix C. ■

Proposition 8 shows that with respect to the crime rate, the direct effects of more intense competition or stricter law enforcement always dominate any possible countervailing indirect effects resulting from an adjustment in the number of firms.

The above analysis establishes that a penalty proportional to profits clearly leads to a positive relationship between the intensity of competition and the incentives for crime. Branco and Villas-Boas (2012) assume that both $f = 1$ and $s = 0$ and similarly arrive at the finding that fiercer competition induces more unlawful practices. The assumption $f = 1$ seems justifiable when a firm will be bankrupted by the imposition of the fine. In the real world, it is indeed sometimes the case that criminal fines exceed a firm's ability to pay (see, e.g., Arlen 2012). However, this does not describe the majority of cases. For example, the fines for environmental violations are usually small (see, e.g., Faure 2009). In most jurisdictions, fines are determined such that their level corresponds to some extent with the harmfulness of the act and/or the gain the firm obtained from engaging in the unlawful practice (see, e.g., Part C of the US Federal Sentencing Guidelines). In the specification used in our baseline model, the correspondence with the harm induced/gain obtained by the firm from undertaking the unlawful practice is modeled by an expected sanction per unit of output. The advantage to the firm is represented by the reduction in marginal production costs.[11]

The fixed sanction may reflect minimal sanction levels, but it is also compatible with punishment for harm imposed on society when harm may not be proportional to output.[12] In summary, we believe that the sanction structure used in Section 3 is generally more descriptive of real-world corporate fines than the assumption that a share of profits will be confiscated. However, it should be noted that the relationship between the intensity of product market competition and incentives for corporate crime are decisively influenced by the assumptions made about the sanctions in force.

[11]As an example in this regard, the Commentary to §8A1.2 for the Federal Sentencing Guidelines specifies the gain from the unlawful act of insufficient product testing as follows: "In such a case, the pecuniary gain is the amount saved because the product was not tested in the required manner."

[12]For example, the Dutch Criminal Code sets out a hierarchy of monetary fines depending on the category of the offense. For a survey of criminal sanctions in the environmental realm see Criminal Penalties in EU Member States Environmental Law', available at ec.europa.eu/environment/legal/crime/.

4.3 Cost uncertainty

In this section, to check the robustness of the results presented in the main part of the paper, we consider a situation in which there is uncertainty about the legal production costs of a firm's rivals. In order to focus on this issue in a simple framework, we analyze a scenario in which the number of firms is equal to two, and the level of net benefit from crime is set at $\Delta = b - qs > 0$.

Each firm in the market is aware of its own legal production costs c_i, $i = 1, 2$, but only knows the common distribution function $H(c)$ for its rival's possible legal costs of production. In addition, both firms know the level of net benefit per unit of output they can obtain by engaging in illegal practices. Analogous to equations (2) and (3), the expected profits of a firm L and a firm C with production costs c_i are given by

$$E\pi_i^L = (p_i - c_i)\left(\frac{1}{2} - \frac{p_i - Ep_j}{T}\right) \tag{33}$$

$$E\pi_i^C = (p_i - c_i + \Delta)\left(\frac{1}{2} - \frac{p_i - Ep_j}{T}\right) - qF, \tag{34}$$

where $i, j = 1, 2$ and $i \neq j$. The first-order conditions with respect to prices lead to optimal price setting according to

$$p_i^L = \frac{T}{4} + \frac{c_i + Ep_j}{2} \tag{35}$$

$$p_i^C = \frac{T}{4} + \frac{c_i - \Delta + Ep_j}{2}, \tag{36}$$

indicating that a firm C will charge lower prices, all else held equal. Using this price-setting rule, we can rewrite expected profits as

$$E\pi_i^L = T\left(\frac{1}{4} - \frac{c_i - Ep_j}{2}\right)^2 \tag{37}$$

$$E\pi_i^C = T\left(\frac{1}{4} - \frac{c_i - \Delta - Ep_j}{2}\right)^2 - qF \tag{38}$$

from which firm i's decision over whether or not to illegally reduce its production costs can be deduced for given expectations about price setting by firm j. Firm i will choose to engage in criminal behavior when $E\pi_i^C > E\pi_i^L$. For Δ approaching zero, the illegal opportunity is not sufficiently attractive; however, as $E\pi^C - E\pi^L$ increases in Δ, crime becomes profitable when the net benefits from crime are sufficiently large. At the same time, the profit difference between types of firms decreases in the legal production costs c_i, since higher production costs reduce a firm's expected output and therefore reduce the gain from illegal practices. Consequently, the benefits from crime are lower for higher legal costs of production, and we can establish a critical cost level c^k such that firm i will engage in illegal practices for $c_i < c^k$ while it otherwise (for $c_i \geq c^k$) chooses to obey the law.

This result, together with the fact that the firms' expectations regarding their rival's costs are symmetric, allows us to express the expected rival's price $Ep_j = Ep$ as

$$Ep = H(c^k)E(p^C|c < c^k) + (1 - H(c^k))E(p^L|c \geq c^k). \tag{39}$$

From this, we can obtain

$$Ep = \frac{T}{2} + Ec - \Delta H(c^k) \tag{40}$$

where Ec represents the unconditional expected costs of the rival firm. Similar to the scenario without uncertainty, the rival's expected price consists of a mark-up dependent on transportation costs and the rival's expected production costs (including the cost savings from criminal behavior). Inserting equation (40) into the profit equations (37) and (38), the equilibrium expected profits of a firm with legal production costs c amount to

$$E\pi(c) = \left\{ \begin{array}{c} \frac{T}{4}\left(1 - \frac{c - Ec + \Delta H(c^k)}{T}\right)^2 \\ \frac{T}{4}\left(1 - \frac{c - Ec - \Delta(1 - H(c^k))}{T}\right)^2 - qF \end{array} \right\} \text{ for } c \left\{ \begin{array}{c} \geq \\ < \end{array} \right\} c^k, \tag{41}$$

where c^k follows from $E\pi^L(c^k) = E\pi^C(c^k)$.

The incentives for engaging in crime in this setting are ultimately best described by the resulting critical cost level c^k. The higher this level, the more likely it is that firms' realized costs will be less than the critical level, such that firms will engage in the criminal activity. How law enforcement and the intensity of competition in the product market affect this critical cost level is described in the following proposition:

Proposition 9 *With uncertainty over costs and two firms in the market, an increase in the intensity of product market competition via reduced transportation costs T has an ambiguous effect on the critical cost level c^k and therefore on the prevalence of crime. The critical* *cost level increases (decreases) with a decrease in T for $\Delta < (>) 2qF$. Stricter law enforcement represented by an increase in s, F, or q reduces the critical cost level and thereby the prevalence of crime.*

Proof. Follows from equation (41) and the condition $E\pi^L(c^k) = E\pi^C$. For details, see Appendix D. ■

Proposition 9 establishes that our findings from Section 3, summarized in Propositions 2 and 3, can be neatly transferred to a duopoly featuring uncertainty about a rival's costs. With more intense competition, crime becomes more prevalent when the net benefits from crime are low; however, the opposite holds for settings characterized by high net benefits from crime. In the first case, the effect of the increase in expected demand implied by the unlawful practice dominates, whereas the lowered price-cost margin makes crime less profitable for high Δ. Stricter enforcement reduces the prevalence of crime.

5 Conclusion

Competition is often blamed when firms utilize unlawful practices to lower their production costs. In light of the fact that such crime can cause considerable social harm, this paper explores the interaction between the intensity of product market competition, incentives for corporate crime, and law enforcement. In our oligopolistic model with horizontally differentiated products and free entry, we establish that a decrease in market entry costs (implying a higher number of firms in the market) decreases corporate crime, whereas an increase in the substitutability of the different products may or may not increase corporate crime. On the one hand, more intense competition makes crime more attractive due to the relatively larger increase in market share a firm can achieve by engaging in criminal behavior. On the other hand, more intense competition reduces price-cost margins, making any increase in market share less profitable. In our setting, which of the two effects dominates is highly dependent on the magnitude of the reduction in production costs enabled by the illegal practices. Crime increases in the intensity of competition for intermediate gains, that is, when the equilibrium before the change was characterized by a relatively low crime rate. In contrast, for settings featuring high benefits from crime and therefore an initially high crime rate, more intense competition may instead reduce incentives for crime.

In our setting, product market incentives are important drivers of decisions concerning illegal practices, and crime deterrence likewise influences the product market. In this regard, our model produces an interesting finding related to the effects of stricter law enforcement on expected profits and market entry decisions. At first glance, higher expected sanctions reduce profits, as they must be borne by firms that choose to engage in criminal practices. However, the deterrence effect of higher sanctions reduces the fierceness of price competition in the market, resulting in higher expected profits. As a result, the effects of different kinds of sanctions may vary. While sanctions proportional to output and therefore to social harm have a positive impact on expected profits, a fixed sanction has a non-linear effect on profits. Consequently, the relationship between the number of competitors entering a market and law enforcement resulting from a fixed sanction may be u-shaped. More generally, the fact that law enforcement implies repercussions on product market competition indicates that policy makers should take these effects into consideration in their attempts to optimize law enforcement. In addition, our finding that corporate crime reduces expected profits in equilibrium may help to explain certain real-world occurrences, such as the emergence of voluntary agreements among firms on standards addressing bribery (see, e.g., the Rules of Conduct set out by the International Chamber of Commerce).

Our analysis suggests that blaming competition exclusively for inducing the illegal conduct of firms may sometimes be unfounded, opening up many avenues for future research. For instance, it may be interesting to consider scenarios in which the benefits from unlawful practices can vary across firms, as well as settings in which these benefits are so high that law-abiding firms are driven out of the market. If consumers' preferences could be shifted to encourage purchasing from law-abiding firms, we would obtain deterrent market incentives via reputation effects in a dynamic setting. Moreover, our analysis has shown that the specifics of the sanctions applied have an impact on the relationship between competition, law enforcement, and crime. This is an important insight that might generalize to other areas of non-compliance, and it underscores the importance of aligning the scholarly representation of sanction with real-world sanction schemes.

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Appendix

A Proof of Proposition 1

For $\alpha^* \in (0,1)$, the partial derivative with respect to n is given by

$$\frac{\partial \alpha^*}{\partial n} = -\frac{2T}{\Delta n^2} < 0. \tag{42}$$

With regard to the first critical net benefit level Δ^{k1}, we obtain

$$\frac{\partial \Delta^{k1}}{\partial n} = -\frac{2}{n^2}\left(\sqrt{T^2 + qFn^2T} - T\right) + \frac{1}{n}\left(T^2 + qFn^2T\right)^{-1/2} 2nqFT > 0. \tag{43}$$

The inequality can be verified by observing that it implies

$$\begin{aligned} n^2qFT &> T^2 + qFn^2T - T\sqrt{T^2 + qFn^2T} \\ 0 &> T - \sqrt{T^2 + qFn^2T}, \end{aligned} \tag{44}$$

which is fulfilled, since the right-hand side of the inequality is negative. With respect to the second critical net benefit level Δ^{k2}, the derivative is given by

$$\frac{\partial \Delta^{k2}}{\partial n} = -\frac{2}{n^2}\left(T - \sqrt{T^2 - qFn^2T}\right) + \frac{1}{n}\left(T^2 - qFn^2T\right)^{-1/2} 2qFnT > 0. \tag{45}$$

The inequality is derived from

$$\begin{aligned} n^2qFT &> T\sqrt{T^2 - qFn^2T} - T^2 + qFn^2T \\ 0 &> \sqrt{T^2 - qFn^2T} - T, \end{aligned} \tag{46}$$

where the term on the right-hand side is smaller than zero.

B Proof of Proposition 2

For $\alpha^* \in (0,1)$, the partial derivative with respect to T is given by

$$\frac{\partial \alpha^*}{\partial T} = -\frac{2}{\Delta}\left(\frac{1}{n} - \frac{qF}{\Delta}\right), \tag{47}$$

which is larger (smaller) than zero when Δ is larger (smaller) than nqF. With regard to the first critical net benefit level Δ^{k1}, the derivative with respect to T can be expressed by

$$\frac{\partial \Delta^{k1}}{\partial T} = \frac{2}{n}\left(\frac{1}{2}(T^2 + qFn^2T)^{-1/2}(2T + qFn^2) - 1\right), \tag{48}$$

which is equal to zero for $F = 0$. To establish the sign of this derivative for $F > 0$, we investigate the cross-derivative

$$\begin{aligned}\frac{\partial^2 \Delta^{k1}}{\partial T \partial F} &= \frac{2}{n}\left(-\frac{1}{4}(T^2 qFn^2T)^{-3/2}(2T + qFn^2)qn^2T + \frac{1}{2}(T^2 + qFn^2T)^{-1/2}qn^2\right)\\ &= \frac{qn}{2}(T^2 + qFn^2T)^{-3/2}\left[-2T^2 - qFn^2T + 2T^2 + 2qFn^2T\right]\\ &= \frac{q^2n^3FT}{2}(T^2 + qFn^2T)^{-3/2} > 0.\end{aligned} \tag{49}$$

In conclusion, $\partial \Delta^{k1}/\partial T > 0$ for $F > 0$.

Turning to the second critical benefit level Δ^{k2}, we establish

$$\frac{\partial \Delta^{k2}}{\partial T} = \frac{2}{n}\left(1 - \frac{1}{2}(T^2 - qFn^2T)^{-1/2}(2T - qFn^2)\right), \tag{50}$$

which is also equal to zero at $F = 0$. The cross derivative in this case is given by

$$\begin{aligned}\frac{\partial^2 \Delta^{k2}}{\partial T \partial F} &= \frac{2}{n}\left(\frac{1}{4}(T^2 - qFn^2T)^{-3/2}(2T - qFn^2)(-qn^2T) - \frac{1}{2}(T^2 - qFn^2T)^{-1/2}(-qn^2)\right)\\ &= \frac{qn}{2}(T^2 - qFn^2T)^{-3/2}\left[-2T^2 + qFn^2T + 2T^2 - 2qFn^2T\right]\\ &= \frac{q^2n^3FT}{2}(T^2 - qFn^2T)^{-3/2} < 0.\end{aligned} \tag{51}$$

In conclusion, $\partial \Delta^{k^2}/\partial T < 0$ for $F > 0$.

C Proof of Proposition 8

The overall effect of the intensity of competition and the law enforcement parameters on the expected crime rate is obtained by combining the respective direct effect on the critical gross benefit $\Delta^{k1} + qs$ and the indirect effect resulting from the subsequent change in the number of competitors.

With regard to the critical benefit level, from equation (28), we obtain

$$\frac{\partial \Delta^{k1}}{\partial T} = \frac{2}{n} \frac{1 - \sqrt{1 - fq}}{\sqrt{1 - qf}} > 0 \tag{52}$$

$$\frac{\partial \Delta^{k1}}{\partial n} = -\frac{2T}{n^2} \frac{1 - \sqrt{1 - fq}}{\sqrt{1 - qf}} = -\frac{T}{n} \frac{\partial \Delta^{k1}}{\partial T} < 0 \tag{53}$$

$$\frac{\partial \Delta^{k1}}{\partial f} = q \frac{2T}{n} (1 - qf)^{-3/2} > 0 \tag{54}$$

$$\frac{\partial (\Delta^{k1} + qs)}{\partial s} = q > 0. \tag{55}$$

From the market entry condition, equation (32), it follows that

$$\frac{\partial \Pi}{\partial n} = -\frac{2T}{n^3} \left(1 - qf \left[1 - G(\Delta^{k1} + qs)\right]\right) + \frac{T}{n^2} qfg(\Delta^{k1} + qs) \frac{\partial \Delta^{k1}}{\partial n} < 0 \tag{56}$$

$$\frac{\partial \Pi}{\partial T} = \frac{1}{n^2} \left(1 - qf \left[1 - G(\Delta^{k1} + qs)\right]\right) + \frac{T}{n^2} qfg(\Delta^{k1} + qs) \frac{\partial \Delta^{k1}}{\partial T} > 0 \tag{57}$$

$$\frac{\partial \Pi}{\partial f} = -\frac{T}{n^2} q \left[1 - G(\Delta^{k1} + qs)\right] + \frac{T}{n^2} q^2 fg(\Delta^{k1} + qs) \frac{\Delta^{k1}}{\partial f} \tag{58}$$

$$\frac{\partial \Pi}{\partial s} = \frac{T}{n^2} q^2 fg(\Delta^{k1} + qs) > 0. \tag{59}$$

The total effect of a change in transportation costs T on the expected crime rate can be deduced from

$$\begin{aligned} \frac{d\Delta^{k1}}{dT} &= \frac{\partial \Delta^{k1}}{\partial T} + \frac{\partial \Delta^{k1}}{\partial n} \frac{dn}{dT} \\ &= \frac{\partial \Delta^{k1}}{\partial T} - \frac{\partial \Delta^{k1}}{\partial n} \frac{\partial \Pi / \partial T}{\partial \Pi / \partial n} \\ &= \frac{\partial \Delta^{k1} / \partial T}{\partial \Pi / \partial n} \left(\frac{\partial \Pi}{\partial n} + \frac{T}{n} \frac{\partial \Pi}{\partial T} \right) \\ &= \frac{\partial \Delta^{k1} / \partial T}{\partial \Pi / \partial n} \left(-\frac{T}{n^3} \left(1 - qf \left[1 - G(\Delta^{k1} + qs)\right]\right) \right) > 0. \end{aligned} \tag{60}$$

For the sanction parameter f, we obtain

$$\begin{aligned}
\frac{d\Delta^{k1}}{df} &= \frac{\partial \Delta^{k1}}{\partial f} + \frac{\partial \Delta^{k1}}{\partial n}\frac{dn}{df} \\
&= \frac{\partial \Delta^{k1}}{\partial f} - \frac{\partial \Delta^{k1}}{\partial n}\frac{\partial \Pi/\partial f}{\partial \Pi/\partial n} \\
&= \frac{1}{\partial \Pi/\partial n}\left(\frac{\partial \Delta^{k1}}{\partial f}\frac{\partial \Pi}{\partial n} - \frac{\partial \Delta^{k1}}{\partial n}\frac{\partial \Pi}{\partial f}\right) \\
&= -\frac{1}{\partial \Pi/\partial n}\frac{T}{n^2}\frac{\partial \Delta^{k1}}{\partial n} q\left[1 - G(\Delta^{k1} + qs)\right] > 0. \qquad (61)
\end{aligned}$$

With regard to the sanction s, we derive

$$\begin{aligned}
\frac{d(\Delta^{k1} + qs)}{ds} &= q + \frac{\partial \Delta^{k1}}{\partial n}\frac{dn}{ds} \\
&= q - \frac{\partial \Delta^{k1}}{\partial n}\frac{\partial \Pi/\partial s}{\partial \Pi/\partial n} \\
&= \frac{1}{\partial \Pi/\partial n}\left(-q\frac{\partial \Pi}{\partial n} + \frac{\partial \Delta^{k1}}{\partial n}\frac{\partial \Pi}{\partial s}\right) \\
&= -\frac{1}{\partial \Pi/\partial n}\frac{2T}{n^3}\left(1 - qf\left[1 - G(\Delta^{k1} + qs)\right]\right) > 0. \qquad (62)
\end{aligned}$$

The effects of a variation in q are equivalent to the effects of a simultaneous proportional increase in f and s.

D Proof of Proposition 9

Using equation (41), one can transform the condition $E\pi^L(c^k) = E\pi^C(c^k)$ into

$$Z \equiv 2\left(T - c^k + Ec - \Delta H(c^k)\right)\Delta + \Delta^2 - 4qFT = 0. \qquad (63)$$

From this, we obtain

$$\frac{dc^k}{dT} = \frac{2\Delta - 4qF}{2\Delta + 2\Delta^2 h(c^k)} \qquad (64)$$

and

$$\frac{dc^k}{dF} = \frac{-4qF}{2\Delta + 2\Delta^2 h(c^k)} < 0, \qquad (65)$$

where $h(c)$ is the density function associated with the cumulative distribution function $H(c)$. With regard to the sanction s, we obtain

$$\frac{dc^k}{ds} = -q\frac{dc^k}{d\Delta} = -q\frac{2(T - c^k + Ec - 2\Delta H(c^k)) + 2\Delta}{2\Delta - 2\Delta^2 h(c^k)}$$
$$= -q\frac{(T - c^k + Ec - \Delta H(c^k)) + \Delta(1 - H(c^k))}{\Delta + \Delta^2 h(c^k)} < 0, \tag{66}$$

where the sign is determined by applying the assumption that a firm L with $c = c^k$ produces a positive quantity. The effect of an increase in the detection probability is again the same as the effect of a simultaneous proportional increase in the sanctions s and F.

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