Explaining Escalating Fines and Prices: The Curse of Positive Selection*

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COMMENTS ARE WELCOME!

Abstract

This paper develops a simple two-period model of behavior-based price discrimination that nests optimal law enforcement with uncertain detection and monopoly pricing with imperfect customer recognition and studies how escalating fine (pricing) schemes may emerge. We show that, in a fixed environment, escalating fines (prices) for repeat offenders (consumers) are driven by the enforcement authority's (seller's) incentive to reduce the fine (price) for low-value offenders (consumers) rather than the incentive to increase the fine (price) for repeat offenders (consumers). Our analysis provides a novel explanation for escalating fines if consumer gains are not fully credited to social welfare.

Keywords: Behavior-based price discrimination, fine, deterrence, escalation
JEL-Classification: D42, L11, L12

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1 Introduction

Escalating fines for repeat offenders are ubiquitous, but they pose a serious challenge for the theory of optimal law enforcement. Why should the fine for a given offense increase with the number of previous offenses? Escalating pricing schemes for repeat consumers (e.g., mobile phone subscribers) pose a similar challenge. Why should loyal customers pay higher prices than new ones? Surprisingly, standard theory struggles with answering these questions when the economic environment does not change over time.

The repeated canonical model of optimal law enforcement (Becker, 1968; Polinsky and Shavell, 2007), for instance, cannot explain escalating fines. Various authors have therefore suggested alternative explanations. For example, if law enforcement is error-prone, accidental and real offenders are more distinguishable when the number of offenses increases; it then makes sense to charge higher fines for repeat offenders (Stigler, 1974; Rubinstein, 1979; Chu et al., 2000; Emons, 2007). Similarly, if repeat offenders learn how to avoid detection, escalating fines may keep notorious offenders deterred (Baik and Kim, 2001; Posner, 2007).[1] Finally, if conviction carries a negative social stigma, escalating fines may keep up deterrence for previously convicted offenders (Rasmusen, 1996; Funk, 2004; Miceli and Bucci, 2005).[2] As we will demonstrate, however, none of these explanations address the underlying price discrimination problem.

The literature on behavior-based price discrimination (Armstrong, 2006; Fudenberg and Villas-Boas, 2007), in turn, seems to suggest that a seller who lacks the ability to commit to future prices might want to increase the price charged to repeat consumers with identifiable high types due to the ratchet effect (Freixas et al., 1985). Yet, recent work by Tirole (2016) on the "positive selection" of high-value consumers (i.e., when exit is absorbing and low-value consumers that do not consume in a given period are thus excluded from consumption for all future periods) cautions against this logic. With positive selection, optimal market segmentation into consumers and non-consumers is shown to be time consistent, such that irrespective of commitment the seller cannot gain by deviating from this segmentation later in the game. This implies that escalation cannot be driven by an incentive to increase the prices charged to identifiable high-value consumers who make repeated purchases. As it turns out, this is the key driver behind the difficulty

[1] Some authors have argued, though, that declining penalty schemes are optimal if law enforcement becomes more effective in pursuing notorious offenders (e.g. Dana, 2001, Mungan, 2009). Similarly, wealth constraints may make decreasing fines optimal (e.g. Anderson et al., 2017), or lead to falling fines for first offenses over time, but constant ones for repeat offenses (Polinsky and Shavell, 1998).

[2] See Miceli (2013) for a survey of the relevant literature.

of the theory of optimal law enforcement to explain escalating fines and is what we call the “curse” of positive selection.

In this paper, we provide a different explanation for escalating pricing schemes based on dynamic pricing in a fixed economic environment. We show that escalation is driven by *decreasing* prices for low-value consumers rather than increasing prices for high-value consumers. The intuition is as follows: If the *seller cannot commit not to lower the price* in the future, some forward-looking consumers strategically delay consumption to benefit from lower prices in the future, which drives a wedge between the optimal price and the cutoff for first-time consumption. This wedge is the source of the price increase for repeat consumers, as the cutoff for repeat offenders is optimally kept constant.

We develop our line of argument in a two-period model of behavior-based price discrimination that nests optimal law enforcement and monopoly pricing as special cases. In line with Gneezy and Rustichini (2000), we view a monetary fine as a price, and we interpret an offense as one unit of consumption. In our setting, an offender is thus a consumer, and the law enforcement authority is a seller. We assume that consumer types are continuously distributed and fixed, and we suppose that the seller and consumers share the same discount factor.[3] In period 1, forward-looking consumers self-select into consumers and non-consumers, and both consumers and non-consumers may consume in period 2 (i.e., exit is non-absorbing). The seller detects consumption with exogenous probability.[4] Customer recognition in period 2 is thus imperfect, which is different from standard models of behavior-based price discrimination. This implies that, in period 2, the seller can distinguish two groups of consumers: repeat consumers recognized from detected previous consumption, and non-recognized consumers who either did not consume in period 1 (‘true’ first-time consumers) or were not detected as consumers in period 1 (‘false’ first-time consumers). The seller can charge three prices for detected consumers: The price for first-time consumers in period 1, the price for (true and false) first-time consumers in period 2, and the price for recognized repeat consumers in period 2.

We derive three key results. First, with commitment the seller cannot do better than setting all prices equal to the optimal static price. The well-known result that it is optimal not to price discriminate with commitment (Stokey, 1979; Hart and Tirole, 1988; Acquisti and Varian, 2005; Fudenberg and Villas-Boas, 2007) thus extends to settings with imperfect customer recognition. It is worth noting that setting all prices equal to the optimal static

[3] We will relax this assumption in subsection 5.1.

[4] That is, in the language of the canonical offender model enforcement is uncertain (Polinsky and Shavell, 2007). In the context of monopoly pricing, the seller faces payment evasion (Buehler et al., 2017). Examples for payment evasion include digital piracy, shoplifting, fare dodging, etc.

price is not uniquely optimal: falling prices for repeat consumers may also be optimal. Yet, it is never optimal for a seller with commitment ability to choose escalating prices. Second, without commitment optimal prices for repeat consumption escalate if and only if optimal prices for first-time consumption decrease. Put differently, escalation (if any) is generated by decreasing prices for low-value consumers rather than increasing prices for repeat consumers with identifiable high types. Escalation is thus explained by the effect that Coasian dynamics (Coase, 1972; Hart and Tirole, 1988) for low-value consumers have on the optimal price for first-time consumption in period 1, which is paid by repeat consumers who are subject to positive selection (Tirole, 2016). Third, optimal prices for repeat consumers do indeed escalate if the seller cannot commit to future prices and gives less than full weight to consumer gains. In contrast, a seller who gives full weight to consumer gains maximizes standard social welfare, sets all prices equal to the social cost of consumption, and has no incentive to lower the price for first-time consumers.

This paper makes a twofold contribution. First, we add to the theory of optimal law enforcement (Polinsky and Shavell, 2007) by providing a novel explanation for escalating fines that builds on behavior-based price discrimination. We develop our explanation in a generalized version of the canonical offender model where offender gains are not necessarily fully credited to welfare. The assumption that offender gains are fully credited to welfare has long been criticized on the grounds that it is difficult to see why illicit individual offender gains should add to social welfare (Stigler, 1974; Lewin and Trumbull, 1990). Our analysis relaxes this assumption and shows that it has prevented the canonical model from addressing escalation in repeated settings, as standard welfare maximization necessarily forces optimal fines down to the social cost of an offense. Our model brings the analysis closer to the distributive view of justice, which suggests that the optimal punishment "appropriately distributes pleasure and pain between the offender and victim" (Gruber, 2010, p. 5).

Second, we contribute to the literature on behavior-based price discrimination by adding two new ingredients to the analysis. The first ingredient is imperfect customer recognition, as the seller may be unable to detect consumption with certainty. Imperfect customer recognition allows us to extend the analysis to settings in which the seller cannot perfectly track the purchase histories of its customers, which is natural in many settings. As mentioned above, the seller may then be unable to distinguish a true from a false first-time consumer in period 2 who is in fact a non-recognized repeat consumer. The paper closest to ours is Conitzer et al. (2012). These authors study the extreme cases of either no recognition or full recognition in a two-period model with repeat purchases. We consider a setting in which customer recognition is imperfect and allow for the full range from no recognition to full recognition. In a recent paper, Belleflamme and Vergote (2016) study imperfect customer identification in a monopoly setting without repeated purchases. Our paper is also related to Villas-Boas (2004). This author studies a setting in which an infinitely-lived firm faces overlapping generations of two-period-lived consumers and cannot distinguish 'young' from 'old' first-time consumers.

The second ingredient we add is non-profit maximization by the seller. This extension allows us to study dynamic pricing if the seller does not maximize profits. As discussed above, we find that a welfare-maximizing seller does not want to discriminate prices, irrespective of commitment. The reason is that a welfare-maximizing seller does not care for payments by consumers as they amount to costless money transfers if full weight is given to consumer gains. The seller thus cannot do better than setting all prices equal to the social cost of consumption. With less weight given to consumer gains, the seller's profit motive kicks in, and prices are optimally being discriminated. As one might expect, prices are highest if no weight is given to consumer utility and the seller acts as a profit-maximizing monopolist.

The remainder of the paper is organized as follows. Section 2 introduces the generalized offender model and derives the optimal static fine, which is equivalent to the standard monopoly price if detection is perfect and zero weight is given to offender gains. Section 3 studies optimal pricing in the two-period version of the generalized offender model, both with and without commitment by the seller. Section 4 illustrates with two examples from dynamic monopoly pricing, assuming that the consumers' type distribution is uniform. Section 5 considers various extensions. Section 6 offers conclusions and directions for future research.

2 Static Model

We build on the canonical model of optimal law enforcement pioneered by Becker (1968) and studied extensively in Polinsky and Shavell (2007). Consider a population of offenders who obtain an individual gain $g \geq 0$ from committing an offense that generates monetary social harm $h \geq 0$. Individual gains are private knowledge and drawn independently from a distribution with density function $z(g)$ and cumulative distribution function $Z(g)$ on $[\underline{g}, \bar{g}]$, with $\bar{g} > h > \underline{g}$ and $z(g) > 0$ for all g, such that neither complete deterrence nor zero deterrence is optimal from a standard welfare perspective. Individuals who commit the act are detected with exogenous probability $\pi \in (0,1]$ and must pay the fine $f \geq 0$.

Individuals are risk-neutral, implying that only offenders whose gain exceeds the expected fine, $g \geq \pi f$, choose to commit the act.[5]

The enforcement authority is assumed to maximize social welfare W, which is defined as the gains consumers obtain from committing the harmful act less the harm caused (Polinsky and Shavell, 2007, p. 413),

$$W(f;h,\pi) = \int_{\pi f}^{\bar{g}} (g-h)dZ(g). \tag{1}$$

Note that the fine f imposed on detected offenders is a socially costless transfer of money from offenders to the enforcement authority, as the offenders' gains are fully credited to social welfare. It is well known that, in this canonical setting, the optimal fine $f^*(h,\pi) = h/\pi$ implements the first-best outcome (see, e.g., Polinsky 2007): Only individuals whose private gain exceeds the social harm ('efficient offenders') commit the harmful act, while all other individuals ('inefficient offenders') are deterred.

The assumption that 'illicit' offender gains are fully credited to welfare has long been criticized in the literature (Stigler, 1974; Lewin and Trumbull, 1990; Polinsky and Shavell, 2007). We relax this assumption and let the enforcement authority maximize a weighted sum of surplus, with weight one given to expected income from fine payments net of social cost, and weight $\alpha \in [0,1]$ given to offenders gains. The enforcement authority's objective function is then given by

$$\Omega(f;h,\pi,\alpha) = \int_{\pi f}^{\bar{g}} (\pi f - h)dZ(g) + \alpha \int_{\pi f}^{\bar{g}} (g - \pi f)dZ(g), \tag{2}$$

which is equivalent to (1) if the enforcement authority gives full weight to offender gains, $\alpha = 1$, and thus maximizes standard welfare. For $\alpha < 1$, offender gains are not fully credited to social welfare, as the enforcement authority gives relatively more weight to net income from fine payments. In fact, for $\alpha = 0$, the enforcement authority focuses exclusively on net income from payments and acts like a profit-maximizing monopolist.

Our first result characterizes the optimal static fine for the generalized canonical offender model.

Proposition 1 (static fine)**.** *Suppose the objective function $\Omega(f;h,\pi,\alpha)$ is strictly quasi-concave, and the enforcement authority gives full weight to expected net income and weight $\alpha \in [0,1]$ to offenders. Then, the optimal static fine satisfies*

$$f^*(h,\pi,\alpha) = \frac{h}{\pi} + \frac{(1-\alpha)[1-Z(\pi f^*)]}{z(\pi f^*)\pi}, \tag{3}$$

with $\partial f^*(h,\pi,\alpha)/\partial\alpha \leq 0$.

[5] Assuming risk neutrality is immaterial as long as risk preferences do not vary over time.

Proof. Straightforward. □

Proposition 1 shows that the generalized offender model covers the full spectrum from standard welfare maximization to profit maximization. If offender gains are not fully credited to welfare ($\alpha < 1$), the optimal fine strictly exceeds the first-best level h/π, such that some efficient offenders with types $g > h$ are deterred. The optimal fine now reflects the enforcement authority's interest in redistributing illicit offender gains to society. Note that complete deterrence is not optimal, even if offender gains are not credited to welfare ($\alpha = 0$). The reason is that the enforcement authority then focuses solely on the expected payments from detected offenders net of social cost and thus behaves like a monopoly. The following corollary is an immediate implication of Proposition 1.

Corollary 1 (static monopoly price)**.** *Suppose the enforcement authority's objective function gives zero weight to offender gains,* $\Omega(f;h,\pi,0)$*. Then, if the social cost satisfies* $h = c$*, consumption is detected with certainty,* $\pi = 1$*, and the fine is relabelled as a price,* $f \equiv p$*, the optimal fine equals the static monopoly price*

$$p^m(c,1,0) = c + \frac{1 - Z(p^m)}{z(p^m)}. \tag{4}$$

Corollary 1 shows that it is natural to view a fine as a price, as suggested by Gneezy and Rustichini (2000). Indeed, the only difference between the Becker (1968) model of optimal law enforcement and a simple monopoly pricing model are the degree to which individuals' utilities are weighted. Although the theory of optimal law enforcement for socially undesirable activities and standard models of behavior-based price discrimination may appear at first sight to be unrelated, the generalized offender model demonstrates that the underlying mechanism is in fact the same. For simplicity we will from now on use the terms "fine" and "price" interchangeably and refer to the law enforcement authority or the seller as the "authority" and to individuals as "consumers." Figure 1 illustrates the generalized static offender model with three different values for α. The shaded area corresponds to the objective function $\Omega(f;h,\pi,\frac{1}{2})$.

3 Dynamic Model

Let us now consider the repeated version of the generalized offender model with two periods $t = 1,2$. Suppose that the authority and consumers share the same discount factor $\delta \in (0,1)$,[6] and assume that the authority can set three fines $\mathbf{f} = \{f_1, f_2, \hat{f}_2\}$ that are

[6] We will relax this assumption in Section 5.1.

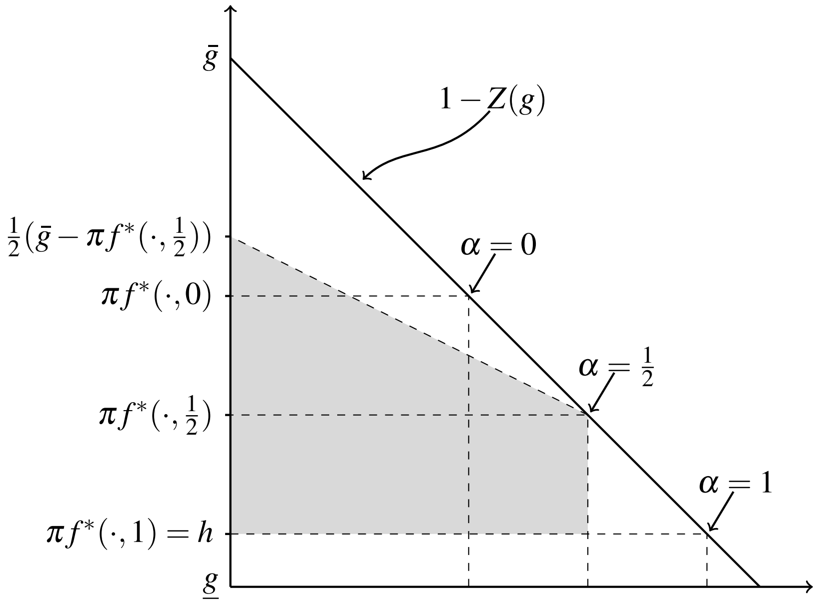


Figure 1: Static model

Notes: The figure shows the optimal price in the generalized offender model with a linear demand function for three different values of α: $0, 1/2$, and 1. The shaded area indicates the objective function Ω for the case of $\alpha = 1/2$.

imposed on detected consumers: f_1 for first-time consumers in period 1, f_2 for first-time consumers in period 2, and $\hat{f}_2$ for repeat consumers in period 2. Finally, assume that consumers are forward-looking and cannot commit to future consumption plans.

3.1 Skimming Property

Since higher types have strictly higher gross surplus, the skimming property (Fudenberg et al. 1985, Cabral et al. 1999, Tirole 2016) holds, which ensures that higher-type consumers make their purchases no later than lower-type consumers. Specifically, if a type g chooses to offend in period t, then so does a higher type $g' > g$. To see how the skimming property works in our setting, consider the gain of a consumer with type g from offending in period 1 and period 2 vs. the gain from offending in period 2 only. For this consumer to offend in period 1, we must have that the gain from offending in period 1 and period 2,

$$\phi_1(g) \equiv g - \pi f_1 + \delta[\pi(g - \pi \hat{f}_2) + (1 - \pi)(g - \pi f_2)],$$

exceeds the gain from offending in period 2 only,

$$\phi_2(g) \equiv \delta(g - \pi f_2).$$

It is straightforward to see that

$$\phi_1(g') - \phi_1(g) > \phi_2(g') - \phi_2(g), \text{ for } g' > g,$$

which implies that there exists a unique cutoff $g_1^*(\mathbf{f})$ which splits the set of agent types into consumers and non-consumers in period 1. Similarly, in period 2 we have that $g' - \pi f_2 > g - \pi f_2$ and $g' - \pi \hat{f}_2 > g - \pi \hat{f}_2$, so that the cutoff for repeat consumers satisfies $\hat{g}_2^*(\hat{f}_2) \geq g_1^*(\mathbf{f})$. The latter inequality follows from the fact that repeat consumers are subject to "absorbing exit" (Tirole, 2016), that is, types $g < g_1^*(\mathbf{f})$ that do not offend in period 1 are eliminated from the set of repeat consumers by construction.[7]

By choosing the menu of fines $\mathbf{f}$, the authority induces individuals to self-select into different demand segments. In doing so, the authority may or may not be able to commit to the menu of fines at the beginning of period 1. We consider each case in turn.

3.2 Commitment

Suppose that the authority is able to commit to the full menu of fines $\mathbf{f}$ at the beginning of period 1. In this case, the fines f_2 and $\hat{f}_2$ applied in period 2 are not conditioned on the consumers' behavior in period 1. It is well known that it is optimal not to price discriminate under commitment if the types of consumers are fixed, and the authority and consumers share the same discount factor (Stokey 1979, Hart and Tirole 1988, Acquisti and Varian 2005, and Fudenberg and Villas-Boas 2007). The next proposition establishes that this result also holds for the generalized offender model with imperfect consumer recognition.

Proposition 2 (commitment)**.** *Suppose the authority can commit to the full menu of fines at the beginning of period 1. Then, it can do no better than set all fines equal to the optimal static fine, that is,* $f_1^* = f_2^* = \hat{f}_2^* = f^*(h, \pi, \alpha)$.

Proof. Consider a high-valuation consumer $g' > g^*$ and a low-valuation consumer $g < g^*$, where g^* is the static optimal cutoff. For the high type to reveal himself, fines must be chosen such that the cutoffs satisfy $g_1^* \leq g_2^*$. Similarly, for the low type to reveal himself, the first-period cutoff must satisfy $g_1^* \geq g^*$. Yet, $g_1^* < g_2^*$ cannot be optimal, as the authority could do better by increasing g_1^* or decreasing g_2^*, thereby bringing the cutoffs closer to their respective optimal levels. Therefore, the unique optimal policy

[7]Note that absorbing exit exclusively applies to repeat consumers. In contrast to Tirole (2016) individuals are allowed to exit and enter the market at will, but they cannot select themselves into the set of repeat consumer after exit.

is to set the fines such that the cutoffs are equal, $g_1^* = g_2^* = g^*$. Profit maximization requires that $g_2^* = \pi f_2^* = \pi f^*(h,\pi,\alpha) = g_1^*$ by Proposition 1. The indifference condition $\phi(g_1^*) = \phi(g_2^*)$ then simplifies to $g_1^* - \pi f_1 + \delta\pi(g_1^* - \pi\hat{f}_2) = 0$, which is satisfied for $f_1^* = f_2^* = \hat{f}_2^* = f^*(h,\pi,\alpha)$. □

Proposition 2 shows that the authority can do no better than achieve the optimal static outcome in both periods: When the authority can commit to the full menu of fines, it is optimal to set the optimal static fine f^* for all consumers and thus abstain from both inter-temporal price discrimination ($f_1 \neq f_2$) and behavior-based price discrimination ($f_2 \neq \hat{f}_2$). It is worth noting that non-discrimination is not uniquely optimal. Decreasing fines for repeat offenders that implement equal cutoffs, $g_1^* = g_2^*$, such that only detected repeat consumers benefit from the lower fine period 2, whereas previously non-detected repeat consumers face the optimal static fine in period 2, are also optimal.[8] Yet, the authority cannot do better with decreasing rather than constant prices. Escalating prices, in turn, cannot be optimal if consumers cannot commit, as individuals cannot be coerced to buy at arbitrary prices.

The result clarifies why the literature on optimal law enforcement has struggled to explain escalating fines in the repeated canonical framework: if the authority has the ability to commit to (expected) fines, it is simply not optimal to escalate fines. Next, we consider a repeated version of the generalized canonical model in which the authority lacks the ability to commit.

3.3 Non-Commitment

Consider a setting in which the authority lacks the ability to commit to the menu of fines at the beginning of period 1. The authority will then want to condition the fines in period 2 on the consumers' observed behavior in period 1 (i.e., whether or not they were previously detected as consumers). As a result, optimal pricing in period 2 must account for both *right*-truncation for first-time consumers (Coase, 1972) and *left*-truncation for repeat consumers (Tirole, 2016), as the cutoff in period 1, g_1^*, separates the type set into non-consumers $[\underline{g}, g_1^*]$ and consumers $[g_1^*, \bar{g}]$, respectively.

To understand the implications of left- and right-truncation for pricing, consider the optimal expected fine for repeat offenders in period 2. In line with Tirole (2016), the left-truncation at g_1^* implies that the optimal expected fine for repeat offenders must be at least as large as the cutoff in period 1, $\pi\hat{f}_2^* \geq g_1^*$, as all previously detected offenders

[8]That is, previously detected repeat consumers are treated differently from previously non-detected repeat consumers.

must have types $g \geq g_1^*$ (otherwise they would not have offended in period 1). This immediately implies that it cannot pay off to strategically consume in period 1: any loss incurred in period 1 cannot be recouped in period 2, as the optimal price for repeat consumption cannot fall. Strategic delay is thus the only way in which agents may benefit from non-myopic behavior (if the expected fines for first-time offenses fall), which implies that the cutoff in period 1 must satisfy $g_1^* \geq \pi f_1^*$. The right-truncation at g_1^*, in turn, does not eliminate all types $g \geq g_1^*$ from the pool of first-time offenders in period 2. The reason is that a share $(1-\pi)$ of the individuals with types $g \geq g_1^*$ who consume in period 1 go undetected.

We now proceed to characterize optimal consumer behavior conditional on types.

Proposition 3 (type sorting)**.** *Suppose that the authority cannot commit to fines. Then, consumers optimally condition their behavior on types as follows:*

(i) Types $g < \min\{\pi f_1, \pi f_2\}$ never offend.

(ii) Types $g \geq \pi \hat{f}_2$ always offend.

(iii) For $f_2 \geq f_1$, consumers behave as if they were myopic, such that types $g \in [\pi f_1, \pi \hat{f}_2)$ offend in period 1 and types $g \in [\pi f_2, \pi \hat{f}_2)$ offend in period 2 if not previously detected.

(iv) For $f_2 < f_1$, types $g \in [\pi f_1, g_1^*)$ strategically delay the offense in period 1 and offend in period 2; types $g \in [g_1^*, \pi \hat{f}_2)$ offend in period 1 and offend in period 2 if not previously detected; types $g \in [\pi f_2, g_1^*]$ offend in period 2.

Proof. We consider each statement in turn.

(i) If $f_1 \leq f_2$, consumers act as if they were myopic. For types $g < \pi f_1$ it is not profitable to offend in period 1, and at best equally unprofitable in period 2. If $f_1 > f_2$, types $g < \pi f_2$ do not find it profitable to offend in period 2, and thus even less so in period 1.

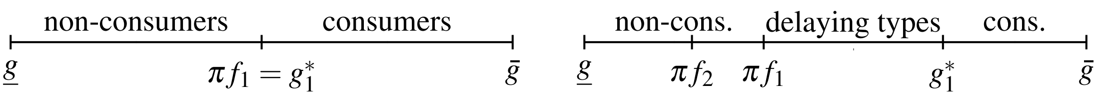
(ii) For types $g \geq \pi \hat{f}_2$ it is always profitable to offend, even at the expected fine $\pi \hat{f}_2 \geq g_1^*$ in period 2, and thus also at the expected fine $\pi f_1 \leq g_1^*$ in period 1.

(iii) For $f_2 \geq f_1$, delaying consumption cannot be profitable by assumption, and agents thus behave as if they were myopic. Therefore, all types $g \geq \pi f_1$ offend in period 1, and all types $g \geq \pi f_2$ that were not previously detected offend in period 2. The result follows from noting that types $g \geq \pi \hat{f}_2$ always offend by (ii).

(iv) For $f_2 < f_1$, it is profitable for types $g \in [\pi f_1, g_1^*)$ to strategically delay consumption in period 1 by construction, and to offend in period 2 when $\pi f_2 < \pi f_1$ by assumption. Similarly, it is profitable for $g \in [g_1^*, \pi \hat{f}_2)$ to offend in period 1 by construction. In period 2, optimal behavior is myopic, and offending is profitable only if not previously detected ($\pi f_2 < g_1^* \leq \pi \hat{f}_2$).

□

Proposition 3 characterizes optimal behavior by consumers based on types. Essentially, two cases need to be distinguished. First, if the expected fine for first-time offenses increases, $f_2 \geq f_1$, forward-looking consumers cannot gain from strategically delaying consumption and behave as if they were myopic. The cutoff in period 1 is then given by $g_1^* = \pi f_1$. This case is illustrated in panel a) of Figure 2. Second, if the expected fine for first-time offenses decreases, $f_2 < f_1$, some forward-looking agents strategically delay the offense to benefit from the lower expected fine in period 2. The cutoff in period 1 then exceeds the myopic level, $g_1^* > \pi f_1$, as illustrated in panel b) of Figure 2.



(a) $f_1 \leq f_2$: myopic　　**(b)** $f_1 > f_2$: strategic delay

Figure 2: Type sorting in period 1

Notes: The figure shows the optimal sorting of consumers by type according to Proposition 3. Panel (a) shows the case of the fines for first-time offenses (weakly) increasing and individuals selecting into consumers and non-consumers. Panel (b) shows the case of the fines for first-time offenses decreasing and individuals selecting into consumers, delaying types, and non-consumers.

Next, we study how the authority optimally chooses fines, accounting for optimal consumer behavior characterized by Proposition 3.

3.3.1 Optimal Pricing in Period 2

We first consider the optimal fine for repeat consumers in period 2, $\hat{f}_2^*$. This fine must maximize the authority's welfare generated by previously detected repeat consumers with types $g \in [g_1^*, \bar{g}]$,

$$\hat{f}_2^* = \arg\max_{\hat{f}_2} \left\{ \int_{\pi \hat{f}_2 \geq g_1^*}^{\bar{g}} (\pi \hat{f}_2 - h) dZ(g) + \alpha \int_{\pi \hat{f}_2 \geq g_1^*}^{\bar{g}} (g - \pi \hat{f}_2) dZ(g) \right\}. \tag{5}$$

Our next result shows how the optimal fine is determined.

Proposition 4 (repeat consumers)**.** *Suppose that the authority cannot commit to fines in period 1. Then,*

(i) if $g_1^* < \pi f^*(h,\pi,\alpha)$, the optimal fine for repeat consumers in period 2 equals the optimal static fine, $\hat{f}_2^* = f^*(h,\pi,\alpha)$.

(ii) if $g_1^* \geq \pi f^*(h,\pi,\alpha)$, the optimal fine for repeat consumers in period 2 keeps the cutoff constant, $\pi\hat{f}_2^* = \hat{g}_2^* = g_1^*$.

Proof. We consider both statements in turn.

(i) For $g_1^* < \pi f^*(h,\pi,\alpha)$, we must have $\hat{f}_2^* = f^*(h,\pi,\alpha)$ by Proposition 1, as consumer behavior is myopic in period 2.

(ii) For $g_1^* \geq \pi f^*(h,\pi,\alpha)$, the objective function in (5) is maximized at the lower bound after left-truncation, $\pi\hat{f}_2^* = \hat{g}_2^* = g_1^*$.

□

Proposition 4 states that the optimal fine for repeat consumers in period 2 equals the optimal static fine if the cutoff in period 1 is below the optimal static cutoff. The intuition for this result is straightforward: since consumers are myopic in period 2 and the left-truncation of the type set at g_1^* does not prevent the authority from reaching the static optimum, it is best to choose the optimal static fine. This finding might suggest that escalation occurs if the initial cutoff is lower than the static optimum. However, as will become clear below, it cannot be optimal for the authority to induce an initial cutoff that is below the static optimum, since this would induce a loss that cannot be recouped in period 2. Henceforth, we therefore focus on the case where g_1^* exceeds the optimal static cutoff.[9]

Proposition 4 demonstrates that if g_1^* exceeds the optimal static cutoff, the optimal cutoff for repeat consumers in period 2 must equal the cutoff from period 1, $\hat{g}_2^* = g_1^*$. That is, the optimal fine for repeat consumers in period 2 is chosen such that no previous consumers are excluded. This result reflects Tirole's (2016) insight that the set of infra-marginal consumers is invariant to left-truncation under positive selection. At first glance, the result is surprising as cutoff invariance obtains even though exit (i.e., non-consumption) is not absorbing in our setting. After all, individuals may choose to consume in period 2 even if they did not consume in period 1. Note, however, that the cutoff invariance result

[9]See Mueller and Schmitz (2015) for an analysis of a setting in which there is an exogenous restriction on the fines for first-time offenders.

holds *only* for detected consumers with types above the cutoff level g_1^* who must have committed the offense in period 1 by construction. Therefore, exit is indeed absorbing for repeat consumers.[10] Exit is clearly not absorbing, though, for consumers with types below the cutoff level g_1^*.

The result sheds further light on why the literature has struggled to explain escalating fines: The notion that repeat offenders in period 2 should pay higher monetary fines than first-time offenders in period 1 *because of identifiably higher private gains* turns out to be incorrect. In a fixed economic environment with a given type distribution, the authority can induce the optimal cutoff g_1^* by the appropriate choice of fines right from the start and does not benefit from the identification of individual offenders (inframarginal consumers) over time.

Next, we determine the optimal fine for consumers in period 2 that were not previously detected, f_2^*. This fine maximizes the authority's welfare generated by true first-time consumers in period 2 with types $g \in [\pi f_2, g_1^*]$ and false first-time consumers who are in fact repeat consumers with types $g \in [g_1^*, \bar{g}]$ that were not previously detected,

$$\begin{aligned} f_2^* &= \arg\max_{f_2} \left\{ \left[\int_{\pi f_2}^{g_1^*} (\pi f_2 - h) dZ(g) + \alpha \int_{\pi f_2}^{g_1^*} (g - \pi f_2) dZ(g) \right] \right. \\ &+ \left. (1-\pi) \left[\int_{g_1^*}^{\bar{g}} (\pi f_2 - h) dZ(g) + \alpha \int_{g_1^*}^{\bar{g}} (g - \pi f_2) dZ(g) \right] \right\}. \end{aligned} \tag{6}$$

The next result shows that the optimal fine for first-time consumers in period 2 is lower than the optimal static fine if the authority does not maximize standard welfare.

Proposition 5 (first-time consumers)**.** *Suppose that the authority cannot commit to fines in period 1. Then, in period 2 the optimal fine for consumers who were not previously detected satisfies*

$$f_2^*(h, \pi, \alpha) = \frac{h}{\pi} + \frac{(1-\alpha)[Z(g_1^*) - Z(\pi f_2^*) + (1-\pi)[1 - Z(g_1^*)]]}{z(\pi f_2^*)\pi}. \tag{7}$$

If the authority gives less than full weight to consumer gains, $\alpha < 1$*, this fine is lower than the optimal static fine,* $f_2^* < f^*(h, \pi, \alpha)$.

Proof. Maximizing the objective function in (6) with respect to f_2 yields f_2^* given in (7), which satisfies $f_2^*(\bar{g}) = f^*(h, \pi, \alpha)$ by Proposition 1. Applying the implicit function theorem to the first-order condition yields $\left.\frac{df_2^*}{dg_1^*}\right|_{\alpha<1} > 0$. For $\alpha < 1$, we must have $f_2^* < f^*(h, \pi, \alpha)$, as complete deterrence cannot be optimal since $h < \bar{g}$ by assumption. □

[10] It is worth noting that Tirole (2016) does not discuss repeated offenses.

Two comments are in order. First, if the authority gives full weight to consumer gains ($\alpha = 1$), the optimal fine for consumers who were not previously detected equals the standard welfare-maximizing fine, $f_2^* = h/\pi$. This finding is intuitive, as standard welfare maximization forces the optimal fine down to the social cost of the offense. Second, if the authority gives less than full weight to consumer gains ($\alpha < 1$), the optimal fine is strictly smaller than the static optimal fine. To understand the intuition for this result, consider the extreme case where the cutoff is at the upper bound of the type set, $g_1^* = \bar{g}$, and note that $f_2^*(\bar{g}) = f^*(h, \pi, \alpha)$. Next, consider a marginal reduction in the cutoff value g_1^*. This reduction eliminates consumers with types just below the cutoff level from the pool of true first-time consumers and adds them to the pool of false first-time consumers, but with probability less than one. For a cutoff level $g_1^* < \bar{g}$, the optimal fine must therefore be lower than the optimal static fine.

3.3.2 Establishing Escalation

We now establish the conditions under which escalation occurs. To do so, we determine the cutoff level $g_1^*(\mathbf{f})$ in period 1 using the indifference condition which equates a consumer's utility from consuming in period 1 and period 2 with the utility from consuming in period 2 only. Specifically, the indifferent type g_1^* must satisfy the condition

$$g_1^* - \pi f_1 + \delta[\pi(g_1^* - \pi \hat{f}_2) + (1 - \pi)(g_1^* - \pi f_2)] = \delta(g_1^* - \pi f_2), \tag{8}$$

where the left-hand side accounts for the fact that a consumer in period 1 faces two possible outcomes: with probability π the offense in period 1 is detected, and the repeat consumer faces the expected fine $\pi \hat{f}_2^*$ in period 2; with probability $(1 - \pi)$ the offense is not detected, and the repeat consumer faces the same expected fine πf_2 as a true first-time consumer in period 2. Now, since $g_1^* - \pi \hat{f}_2 \leq 0$ by Proposition 4, a previously detected consumer will either not offend (if $g_1^* - \pi \hat{f}_2 < 0$), or get a zero surplus from offending (if $g_1^* - \pi \hat{f}_2 = 0$) in period 2. In both cases, the second term is zero, such that the indifference condition simplifies to

$$g_1^* - \pi f_1 = \delta \pi (g_1^* - \pi f_2). \tag{9}$$

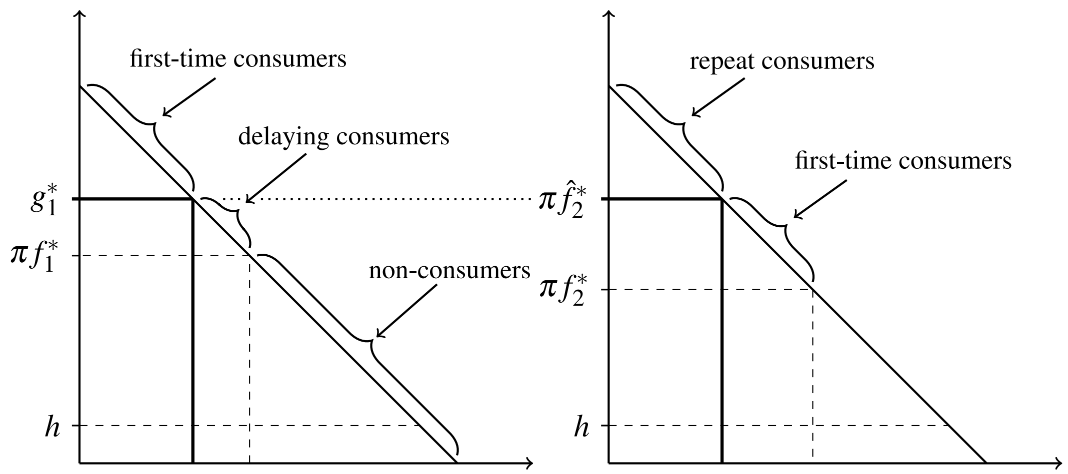
We can now derive the following result.

Proposition 6 (escalation). *Suppose that the authority cannot commit to fines in period 1. Then, optimal fines for repeat consumers escalate, $\hat{f}_2^* > f_1^*$, if and only if the optimal fines for first-time consumers decrease, $f_2^* < f_1^*$.*

Proof. Suppose the optimal fines for first-time consumers decrease, $f_2^* < f_1^*$. Then, using (9), we have $g_1^*(f_1^*, f_2^*) > \pi f_1^*$. Since $g_1^* \leq \pi \hat{f}_2^*$ by Proposition 4, we must have $\pi \hat{f}_2^* > \pi f_1^*$ and thus $\hat{f}_2^* > f_1^*$. This establishes sufficiency.

To establish necessity, assume that $\hat{f}_2^* > f_1^*$, and thus $\pi \hat{f}_2^* > \pi f_1^*$. Since the optimal cutoff in period 1 must satisfy $g_1^* \geq \pi f^*(h, \pi, \alpha)$, we must have $\pi \hat{f}_2^* = \hat{g}_2^* = g_1^* > \pi f_1^*$ by Proposition 4. The latter inequality requires $f_2^* < f_1^*$ by (9). $\square$

Proposition 6 highlights that escalating fines for repeat consumers (if any) follow from *decreasing* fines for low-value consumers rather than increasing fines for identifiable high-value consumers. The prospect of decreasing fines induces some consumers with types above the expected fine to strategically delaying consumption, which in turn drives a wedge between the expected fine πf_1^* and the cutoff g_1^* in period 1. This is illustrated in panel (a) of Figure 3. The wedge these delaying consumers cause gives rise to escalation, $\hat{f}_2^* > f_1^*$, because by Proposition 4 the cutoff is invariant from period 1 to period 2, $g_1^* = \pi \hat{f}_2^*$, which is illustrated in panel (b) of Figure 3. In contrast, if there is no wedge between the expected fine and the cutoff, $\pi f_1^* = g_1^*$, cutoff invariance yields constant fines $\pi f_1^* = \pi \hat{f}_2^*$.



(a): first-period prices

(b): second-period prices

Figure 3: Dynamic model without commitment

Notes: The figure illustrates the optimal prices and induced intertemporal cutoff with a linear demand function when the authority cannot commit. Panel (a) depicts the first period and shows the wedge between cutoff and expected fine that delaying consumers cause. Panel (b) depicts the second period and shows the resulting escalation in price for repeat consumers.

The result combines insights from positive selection (Tirole, 2016) and behavior-based price discrimination (Armstrong 2006, Fudenberg and Villas-Boas 2007) to show that escalating pricing schemes do emerge in a fixed environment if the authority cannot commit not to lower the price for first-time consumption. The following corollary is an immediate implication.

Corollary 2. *Suppose that the authority cannot commit to fines in period 1 and attaches weight $\alpha < 1$ to consumers. Then, optimal fines escalate,*

$$\hat{f}_2^* > f_1^* > f_2^*. \tag{10}$$

Proof. By Proposition 5, $f_2^* < f^*(h, \pi, \alpha)$ for $\alpha < 1$. The indifference condition (9) then immediately implies that $g_1^* > \pi f_1^* > \pi f_2^*$. Substituting $g_1^* = \pi \hat{f}_2^*$ by Proposition 4 yields the result. □

The result clarifies that, without commitment, the authority has an incentive to lower the price for first-time consumption if less than full weight is given to consumers gains. The intuition for this result is straightforward: if full weight is given to consumer gains, fine payments are irrelevant, and fines are optimally set equal to the social cost of the offense, h/π, as everyone with $g \geq h$ must be induced to consume. There is thus no incentive to lower the price for first-time consumption. However, if less than full weight is given to consumer gains, the profit motive kicks in, and the authority has an incentive to lower the price to maximize the income from first-time consumers in period 2.

4 Examples

We illustrate our above analysis with two examples for dynamic monopoly pricing that share the common assumption that types are uniformly distributed on $[0, 1]$. In these examples, it is straightforward to calculate closed-form solutions for the optimal prices.

4.1 Behavior-Based Monopoly Pricing

Armstrong (2006, pp. 6) studies behavior-based monopoly pricing in a two-period setting, assuming that (i) production is costless, $h = 0$, (ii) consumption is perfectly detected, $\pi = 1$, and (iii) zero weight is given to consumer gains, $\alpha = 0$. This setting is a special case of the generalized offender model considered in Section 3 in which prices $\mathbf{p} = \{p_1, p_2, \hat{p}_2\}$ (rather than fines) are chosen so as to maximize intertemporal profits.

With commitment, it is optimal not to discriminate prices and set all prices equal to the static monopoly price $p_1^* = p_2^* = \hat{p}_2^* = p^m = \frac{1}{2}$. This result is a special case of Proposition 2. If the monopolist lacks the ability to commit, prices are chosen so as to maximize intertemporal profits

$$\pi_1 + \delta \pi_2 = p_1(1 - g_1^*) + \delta[\hat{p}_2(1 - g_1^*) + p_2(g_1^* - p_2)],$$

where the price for repeat consumers in period 2 is $\hat{p}_2^* = p^m = \frac{1}{2}$ if $g_1^* < p^m$ and $\hat{p}_2^* = g_1^*$ if $g_1^* \geq p^m$, which is in line with Proposition 4. The price for first-time consumers in period 2 must account for right-truncation and is given by $p_2^* = \frac{1}{2} g_1^*$, which is in line with Proposition 5. Using these prices, it is straightforward to solve the indifference condition for the cutoff $g_1^*(p_1) = (2p_1)/(2-\delta)$. Maximizing over p_1 then yields the profit-maximizing prices (Armstrong, 2006)

$$p_1^* = \frac{4-\delta^2}{2(4+\delta)}; \quad p_2^* = \frac{2+\delta}{2(4+\delta)}; \quad \hat{p}_2^* = \frac{2+\delta}{(4+\delta)}.$$

The monopolist thus practices behavior-based price discrimination as analyzed above: Prices for repeat consumers turn out to be escalating because the monopolist cannot resist the temptation to lower the price for low-type consumers who have not consumed in period 1 (not because repeat consumers face higher prices when they have revealed their high types).

4.2 Dynamic Monopoly Pricing with Absorbing Exit

Tirole (2016) studies dynamic monopoly pricing as an example of sequential screening with positive selection, assuming that consumers can consume in period 2 only if they have consumed in period 1 (absorbing exit). It is assumed that (i) production is costly, $h = c$, (ii) consumption is perfectly detected, $\pi = 1$, and (iii) zero weight is given to consumer gains, $\alpha = 0$. Since types $g < g_1^*$ cannot consume in period 2 by assumption, first-time consumption in period 2 is excluded and the monopolist chooses two prices only, p_1 and $\hat{p}_2$. This setting is a special case of the generalized offender model considered in Section 3 in which only types above g_1^* stay in the market.

It is shown that, with commitment, it is optimal not to discriminate prices and set all prices equal to the static monopoly price

$$p_1^* = \hat{p}_2^* = p^m = \frac{1+c}{2},$$

which is in line with Proposition 2. More interestingly, the same result holds even if the monopolist cannot commit. The intuition for this result is based on Proposition 4. Since exit is absorbing by assumption, all types $g < g_1^*$ below the cutoff are excluded in period 1, such that the monopolist is not tempted to lower the price for non-consumers below the static monopoly price. The profit-maximizing price for the remaining types $g \geq g_1^*$, in turn, is still the static monopoly price, which is the lower bound after the left-truncation. This is a special case of the cutoff invariance result of Proposition 4.

5 Extensions

We now consider several extensions. First, we allow for heterogenous discount factors in the fixed-environment setting analyzed above. Second, we discuss changes in the environment which may provide alternative explanations for escalating pricing schemes.

5.1 Heterogenous Discount Factors

So far we have assumed that the authority and the consumers share a common discount factor δ. We now consider settings in which the authority and the consumers have different discount factors, or $\delta_a \neq \delta_c$. With heterogeneous discount factors, the same surplus arising in period 2 is valued differently by the authority and consumers in period 1. This suggests it may be beneficial for the authority to shift surplus gained by consumers from one period to the other, while keeping the overall consumer surplus constant. For example, if consumers value surplus tomorrow relatively less, $\delta_a > \delta_c$, the authority can offer them a lower surplus tomorow in exchange for a higher surplus today by adjusting the prices accordingly. Specifically, the authority has an incentive to *backload* the fines ($f_1 < f_2$) when it is more patient than the consumers, $\delta_a > \delta_c$, and *frontload* the fines ($f_1 > f_2$) when it is less patient, $\delta_a < \delta_c$. Despite these additional incentives, however, the next result establishes that heterogeneous discount factors do not in fact provide a new rationale for escalating fines.

Proposition 7 (heterogeneous discounting)**.** *Suppose that the authority and the consumers have different discount factors, $\delta_a \neq \delta_c$. Then,*

(i) without authority commitment, escalating fines are optimal for $\alpha < 1$.

(ii) with authority commitment and $\delta_a > \delta_c$, constant fines are optimal.

(iii) with authority commitment and $\delta_a < \delta_c$, frontloaded fines for repeat consumers are optimal and satisfy $f_1^* = f^*(1 + \pi\delta_c) > \hat{f}_2^* = 0$.

Proof. Consider the three statements in turn.

(i) Propositions 3-5 continue to apply as they are independent of the discount factors (δ_a, δ_c). Proposition 6 relies on the consumers' indifference condition, which now reads $g_1^* - \pi f_1 = \delta_c(g_1^* - \pi f_2)$ rather than (9). As before, this implies that $g_1^*(f_1^*, f_2^*) > \pi f_1^*$, and since Proposition 4 continues to hold, the results of Proposition 6 and Corollary 2 still apply.

(ii) As established in the proof of Proposition 2, with authority commitment the unique optimal policy is to set the fines such that the cutoffs satisfy $g_1^* = g_2^*$. Since consumers cannot commit, optimality requires that $g_2^* = \pi f_2^* = \pi f^*(h,\pi,\alpha) = g_1^*$. The indifference condition then reads $g_1^* - \pi f_1 + \delta_c \pi(g_1^* - \pi \hat{f}_2) = 0$, which is satisfied for $f_1^* = f_2^* = \hat{f}_2^* = f^*(h,\pi,\alpha)$.

(iii) As established in (ii), with authority commitment the cutoffs satisfy $g_1^* = g_2^*$, and $g_2^* = \pi f_2^* = \pi f^*(h,\pi,\alpha)$. If $\delta_a < \delta_c$, the authority can strictly gain by transferring its surplus in period 2 to consumers in exchange for extracting their surplus in period 1. Optimality requires that the authority's period-2 surplus is fully transferred, which immediately implies that $\pi \hat{f}_2^* = 0$. The indifference condition then reads $g_1^* - \pi f_1 + \delta_c \pi g_1^* = 0$, which yields $f_1^* = f^*(1+\delta_c \pi)$.

□

Proposition 7 demonstrates that heterogenous discount factors cannot explain the emergence of escalating fines. Even though the authority has an incentive to backload the fines when it is more patient than consumers, $\delta_a > \delta_c$, our previous results on the optimal structure of fines are not affected regardless of authority commitment. The intuition for this result is straightforward: Because the authority cannot coerce consumers into buying at prices at which they would not voluntarily buy from a myopic perspective in period 2, it cannot gain from lowering fines in period 1 in exchange for increasing fines in period 2. Thus, it can never profitably act on its incentive to backload.

However, heterogenous discount factors may instead yield decreasing fines. If the authority can commit and is less patient than consumers, $\delta_a < \delta_c$, forward-looking repeat consumers will accept frontloaded fines that compensate them for a loss in period-1 surplus with an appropriate gain in period-2 surplus. As the authority can strictly gain from transferring period-2 surplus to repeat consumers in exchange for higher period-1 surplus, it will optimally give up its total surplus in period 2, so that consumers pay once for the consumption of the good across both periods. In effect, the authority charges a fine in the first period that maximizes the total payment for the two periods subject to the constraint that the total surplus of repeat consumers is at least as large as that generated by constant fines.

Finally, note that frontloading is impossible if the authority cannot commit. This follows immediately from the fact that consumers are forward-looking. Without authority commitment, consumers will not accept frontloaded fines, as they correctly anticipate that the authority will not want to lower the fine below the optimal static level in period 2 to compensate for the higher fine in period 1. And with consumers therefore choosing to behave as if they were myopic in period 1, the authority is unable to keep the cutoff constant when increasing the first-period fine and cannot benefit from frontloaded fines.

5.2 Changes in the Economic Environment

The preceding analysis has focused on dynamic pricing in a fixed economic environment. However, there may be scenarios in which prices escalate because of changes in the economic environment. For example, a number of authors in the literature on explaining escalating fines have considered the effect of a lower detection probability for repeat offenders (e.g. Baik and Kim, 2001). In this section, we consider two exogenous parameter changes that give rise to such changes in the economic environment. One, an increasing social cost of consumption, and two, a decreasing detection probability in the number of offenses.

5.2.1 Increasing Social Cost of Consumption

Proposition 8 (increasing social cost)**.** *Suppose the social cost of consumption h is known to increase over time, so that $h_2 > h_1$. Then*

(i) with authority commitment, the authority cannot do better than setting the fines equal to the respective optimal static fines, $f_1^* = f^*(h_1, \pi, \alpha)$ and $f_2^* = \hat{f}_2^* = f^*(h_2, \pi, \alpha)$, and hence $f_1^* < \hat{f}_2^* = f_2^*$.

(ii) without authority commitment, the increase in the social cost of consumption reduces the incentive to lower the fine for first-time consumption and eliminates behavior-based discrimination altogether if $\pi f_2^*(h_2, \pi, \alpha) \geq g_1^*$.

Proof. Consider each statement in turn.

(i) With authority commitment, optimality requires that the authority avoids strategic delay by consumers and accounts for the increase in the social cost of consumption. By Proposition 1, it is optimal for the authority to set the fines such that $\hat{g}_2^* = g_2^* = \pi \hat{f}_2 = \pi f_2^* = \pi f^*(h_2, \pi, \alpha)$ and $g_1^* = \pi f_1^* = \pi f^*(h_1, \pi, \alpha)$. The result follows from $h_2 > h_1$.

(ii) By Proposition 5, $f_2^*(h, \pi, \alpha)$ is increasing in the social cost of consumption h. By Proposition 6, behavior-based escalation occurs if and only if $f_2^* < f_1^*$, which is not possible when $\pi f_2^*(h_2, \pi, \alpha) \geq g_1^*$.

□

Proposition 8 shows how an increase in the social cost of consumption gives rise to escalating fines. It is unsurprising that, with authority commitment, it continues to be optimal to charge the optimal static fine in each period. The key difference to Proposition 2 is that the optimal static fine in period 2 increases mechanically due to the change in h, giving rise to escalating fines even with authority commitment.

More interestingly, the result shows that, without authority commitment, an increase in the social cost of consumption may eliminate behavior-based price discrimination. If the optimal static fine for detected first-time consumers in period 2 (i.e., after the increase in social cost) lies at or above the cutoff g_1^*, the authority no longer benefits from lowering the fine. This ensures that consumers remain myopic, since they cannot gain from delaying consumption. In this case, the outcome is the same as under authority commitment: the optimal static fine in period 2 increases mechanically due to the change in h.

5.2.2 Decreasing Detection Probability

Proposition 9 (decreasing detection probability)**.** *Suppose the probability of detection is known to decrease in the number of detections, so that $\pi_2 < \pi_1$. Then,*

(i) with authority commitment, the authority cannot do better than setting $\pi_1 f_1^* = \pi_2 \hat{f}_2^*$ and hence $f_1^* < \hat{f}_2^*$.

(ii) without authority commitment, escalating fines are optimal for $\alpha < 1$.

Proof. Consider the two statements in turn.

(i) Under authority commitment, it must still be that $g_1^* = g_2^* = \pi_1 f_2$. The indifference condition then becomes $g_1^* - \pi_1 f_1 + \delta\pi_1(g_1^* - \pi_2 \hat{f}_2) = 0$, which as before is satisfied for $\pi_1 f_1^* = \pi_2 \hat{f}_2^*$. With $\pi_1 > \pi_2$, it follows immediately that $\hat{f}_2^* > f_1^*$.

(ii) The change in the detection probabilities does not affect the optimal cutoff values under non-commitment, which give rise to escalating fines for $\alpha < 1$ by Corollary 2. Optimal fines must now compensate for the decrease in the detection probability and thus continue to escalate.

□

Proposition 9 demonstrates that our analysis generalizes naturally to settings in which consumers are known to become more effective at avoiding detection after having been fined for an offense. If the authority is able to commit, it still cannot do better than obtain the optimal static surplus in each period. Yet, because the detection probability for repeat consumers decreases, the fine for repeated consumption must increase to compensate. This is directly in line with the finding in Proposition 8. Similarly, if the authority is unable to commit, optimal fines continue to escalate, as they must implement the same cutoff values and therefore increase even more than in the standard setting to compensate for the decrease in the detection probability. As such, if consumers become more difficult to detect after they have been caught previously, then with or without authority commitment, the fines will indeed escalate. However, the key results developed in our main analysis continue to apply.

6 Conclusion

We have studied how escalating pricing schemes emerge in a fixed economic environment in which consumer types are private knowledge, the authority imperfectly recognizes previous consumers, and the authority and consumers share a common discount factor. The key insight of our analysis is that price escalation is driven by an incentive to *reduce* the price for low-value consumers, rather than an incentive to increase the price for high-value repeat consumers. The intuition for this result is as follows: if the authority cannot commit not to lower the price in the future, some forward-looking consumers strategically delay consumption to benefit from lower prices in the future, which drives a wedge between the optimal price and the cutoff for first-time consumption. This wedge is the source of the price increase for repeat consumers, as the positive selection of repeat consumers dictates that the optimal price for repeat consumers keeps the cutoff constant.

Our analysis highlights that escalating pricing schemes emerge in a fixed economic environment if the authority (i) lacks the ability to commit, and (ii) gives less than full weight to consumer gains. In doing so, our paper provides a novel explanation for escalating fines in the repeated offender model if offender gains are not fully credited to welfare. In the extensions, we show that heterogenous discount factors cannot explain escalating pricing schemes, while exogenous changes in the economic environment may well do so.

Our analysis suggests various avenues for future research. First, one could study how commitment by consumers affects the scope for escalating pricing schemes. Second, one might examine how competition among sellers affects the scope for escalating pricing schemes. Third, it would be interesting to provide systematic empirical evidence on escalating prices. We hope to address these issue in future research.

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