Payment Evasion

Stefan Buehler
Daniel Halbheer
Michael Lechner

CESIFO WORKING PAPER NO. 5342
CATEGORY 11: INDUSTRIAL ORGANISATION
MAY 2015

Presented at CESifo Area Conference on Applied Microeconomics, March 2015

ISSN 2364-1428

CESifo *Working Paper No. 5342*

Payment Evasion

Abstract

This paper models payment evasion as a source of profit by letting the firm choose the purchase price and the fine imposed on detected payment evaders. For a given price and fine, the consumers purchase, evade payment, or choose the outside option. We show that payment evasion leads to a form of second-degree price discrimination in which the purchase price exceeds the expected fine faced by payment evaders. We also show that higher fines do not necessarily reduce payment evasion. Using data on fare dodging on public transportation, we quantify expected fines and payment evasion.

JEL-Code: L120.

Keywords: pricing, fine, price discrimination, deterrence.

Stefan Buehler
University of St. Gallen
Institute of Economics (FGN)
Varnbüelstrasse 19
Switzerland – 9000 St. Gallen
stefan.buehler@unisg.ch

*Daniel Halbheer**
HEC Paris
Department of Marketing
1 rue de la Libération
France – 78351 Jouy-en-Josas Cedex
halbheer@hec.fr

Michael Lechner
University of St. Gallen
Swiss Institute for Empirical Economics Research (SEW)
Varnbüelstrasse 14
Switzerland – 9000 St. Gallen
michael.lechner@unisg.ch

*corresponding author

April 2015
We are grateful to the Zurich Transport Network ZVV, Hofwiesenstrasse 370, 8090 Zurich, and in particular to Peter Nordenson, for providing the data. We further thank Berno Büchel, Preyas Desai, Aaron Edlin, Daniel Garrett, Oded Koenigsberg, Liat Levontin, Volker Nocke, Markus Reisinger, Philipp Schmidt-Dengler, and seminar participants at the Annual International Industrial Organization Conference 2015 (Boston), the Annual Meeting of the Committee for Industrial Economics 2015 (Berlin), the CESifo Area Conference on Applied Microeconomics 2015 (Munich), HEC Paris, Telecom ParisTech, the University of Hamburg, the University of Lausanne, the University of Nuremberg, and the University of St. Gallen for helpful comments and suggestions.

1 Introduction

Payment evasion—fraudulent consumption by nonpaying consumers—presents a major challenge for many firms.[1] There are various ways to obtain a product or service without payment, including shoplifting (Yaniv 2009, Perlman and Ozinci 2014), wardrobing (Timoumi and Coughlan 2014), and digital piracy (Chellappa and Shivendu 2005, Vernik et al. 2011). Perhaps the classic example of payment evasion is fare dodging on public transportation (Boyd et al. 1989, Kooreman 1993). Standard price theory abstracts from payment evasion and posits the excludability of nonpaying consumers based on pricing alone. Or, as Hirshleifer et al. (2005, p. 19) put it, "To acquire a commodity buyers must be willing to pay the market price". The implicit assumption, of course, is that the cost associated with payment evasion is high enough to prohibit consumers from fraudulent consumption. It is well known, though, that nonexcludability is prevalent (Novos and Waldman 1984).

We take a different view of payment evasion and model it as a source of profit for the firm. The starting point of our analysis is the observation that, in many markets, firms are able to collect fines—limited to a maximum admissible level mandated by law—from consumers detected as payment evaders.[2] There are thus two sources of revenue for the firm: paying consumers and detected payment evaders. We first develop a theoretical model in which the firm chooses both the purchase price and the fine imposed on detected payment evaders.[3] Observing the price and the fine, consumers can purchase, evade payment, or choose the outside option. The extent of payment evasion is thus endogenously determined by the interplay of firm and consumer decisions.[4]

We derive three key results on pricing. First, paying consumers "overpay" because the firm charges a higher price than it would in the absence of payment evasion. The reason is that an increase in the price turns some paying consumers into payment evaders rather than driving them out of the market. In effect, therefore, payment evasion allows the firm

[1]For example, recent evidence from the United States shows that shoplifters steal more than $13 billion worth of goods from retailers every year (National Association for Shoplifting Prevention 2014). Similarly, consumption of digitally pirated music by U.S. internet users in 2008 is estimated to be between $7 billion and $20 billion (Frontier Economics 2011).

[2]Retailers, for instance, regularly impose in-store penalties for shoplifting. Under New York's state law, retailers may collect a penalty "not to exceed the greater of five times the retail price of the merchandise" (N.Y. GOB. LAW §11-105).

[3]In line with Gneezy and Rustichini (2000), the fine can be viewed as the price faced by a detected payment evader.

[4]Modeling payment evasion in this way provides a natural extension of standard price theory. Alternatively, one might assume that an exogenous share of consumers are "born" payment evaders who never pay or exit the market (irrespective of price or fine). Yet, such an assumption can explain neither the emergence of payment evasion nor the choice of the price and fine in the presence of payment evasion.

to sell a product at different prices to different consumers. Paying consumers pay the purchase price whereas payment evaders face the expected fine. Put differently, payment evasion leads to a form of second-degree price discrimination in which the purchase price exceeds the expected fine—otherwise, there would be no payment evasion—and individuals self-select into paying consumers and payment evaders. Second, the impact of an increase in the binding maximum admissible fine on payment evasion is ambiguous. The intuition for this result is that an increase in the fine not only has a direct negative effect on payment evasion but also generates an upward pressure on the purchase price. For payment evasion to be reduced, the direct effect must dominate the price-mediated effect. Third, we show that the result on price discrimination generalizes naturally to a setting in which the firm can endogenously choose the detection probability through its choice of costly effort.

We then apply our model to comprehensive data on detected payment evaders on the *Zurich Transport Network*, a large Swiss public transportation operator. We find that men and young adults are significantly overrepresented among payment evaders. The probability of detection is as low as 1.3% on average. This implies that even the cheapest ticket price exceeds the expected fine, which is consistent with our theoretical analysis. In addition, an increase in fines is not associated with a smaller number of detected payment evaders. This is explained by the concurrent changes in the detection probability and market size (measured by the total number of passengers).

We intend to make a theoretical and an empirical contribution. On the theoretical side, we introduce the notion of payment evasion into the literature on pricing and show that it naturally leads to a form of second-degree price discrimination in which a good is sold at different prices to purchasing consumers and payment evaders (Phlips 1983, Anderson and Dana 2009). Our optimal pricing rule takes payment evasion explicitly into account and extends the classic Ramsey pricing rule (Ramsey 1927) to this setting. Importantly, the extent of payment evasion is endogenously determined by the interplay of profit maximizing decisions by the firm and rational consumer choices (Becker 1968, Ehrlich 1996).[5] Our model is also related to the analysis of damaged goods (Deneckere and McAfee 1996). The key difference is that, in our case, payment evaders can be fined—but not excluded—from consumption. As a consequence, the firm must deal with both paying consumers and payment evaders, whereas with damaged goods the firm can select the product lines to offer.

On the empirical side, we provide evidence on payment evasion that is consistent with our theoretical analysis using micro data from fare dodging on public transportation. Fare

[5]Rational consumer choices also give rise to payment evasion under pay-as-you-wish pricing (Chen et al. 2013, Schmidt et al. in press). However, under such a pricing scheme, payment evasion is tolerated by the firm and not subject to a fine.

dodging offers an ideal opportunity to study payment evasion since we can obtain detailed information about a large number of detected payment evaders, something that is very difficult to come by in other industries. Our empirical analysis adds to the literature on the effect of enforcement on unlawful behavior (Levitt 1997, DiTella and Schargrodsky 2004, DeAngelo and Hansen 2014) by incorporating the perspective of private (rather than public) law enforcement. It also complements earlier empirical work on digital piracy in the music and movie industries (Rob and Waldfogel 2006, 2007, Zentner 2006, Oberholzer-Gee and Strumpf 2007, Waldfogel 2012, Peukert et al. 2013).

We organize the remainder of the paper as follows. Section 2 introduces the model and describes how consumers self-select into paying consumers and payment evaders. Section 3 examines the profit maximizing management of payment evasion. Section 4 considers two extensions in which the firm has additional tools to deal with payment evasion. Section 5 provides empirical evidence on payment evasion using data on fare dodging. Conclusions and directions for future research are offered in Section 6.

2 The Model

We first introduce the decision-makers in our model: the firm and consumers. Next, we characterize self-selection by consumers and derive the segment-specific demand functions faced by the firm.

2.1 Firm

We consider a firm that offers a product (or service) to paying consumers and payment evaders. The firm chooses the price p at which it sells the product and the monetary fine f that is imposed on detected payment evaders. The fixed cost of providing the product is $F > 0$, and $c \geq 0$ denotes the constant unit cost. We let (π, F_π) describe the detection technology that allows the firm to detect payment evaders with probability $\pi \in [0,1]$ after investing $F_\pi > 0$.[6] For $\pi < 1$, detection is uncertain and assumed to be equally likely for all consumers (Polinsky and Shavell 2000).

In line with Becker (1968), we assume that the monetary fine is limited by legal requirements.[7] Formally, this means that the fine set by the firm cannot exceed the maximum admissible fine $\bar{f}$, where $0 \leq \bar{f} < +\infty$. In addition, we assume that $\pi \bar{f} \geq c$, meaning that the detection technology is "sufficiently effective." If no such technology were available, the firm could not recoup the unit cost even with the highest possible

[6]We relax the assumption of an exogenous detection probability in Section 4.1.

[7]The highest conceivable monetary fine is the wealth of a payment evader, which the firm usually cannot appropriate.

expected fine, which in turn would imply that payment evasion cannot be a source of profit for the firm.

2.2 Consumers

We consider a market with a mass N of potential consumers who observe the price p and the fine f before making a choice. Consumers have unit demand and choose among one of three options: (i) purchase the product, (ii) obtain the product but evade payment, or (iii) the outside option (forgo consumption). When purchasing, a consumer obtains the product at price p. When evading payment, a consumer obtains the product, incurs the evasion cost $k \geq 0$, and faces the risk of being fined in amount f. The evasion cost may reflect the difficulty of obtaining the product without payment or the moral cost of evading payment (Chellappa and Shivendu 2005). Consumers are risk-neutral and have identical beliefs, $\phi \in [0,1]$, about the detection probability π.

2.3 Demand Segments

Suppose that consumers have an indirect utility function that allows them to rank the options in a consistent and unambiguous manner. Preference heterogeneity is captured by the type θ, which represents a consumer's marginal willingness to pay for quality (Mussa and Rosen 1978). The types are drawn independently from a distribution with density function $g(\theta)$ and cumulative distribution function $G(\theta)$ on $[0,+\infty)$, where $g(\theta) > 0$ for all θ, $G(0) = 0$, and $G(+\infty) = 1$. Specifically, a consumer with type θ has the indirect utility function

$$V(p,f;\theta,\phi,k) = \max\{v_P(p;\theta), v_E(f;\theta,\phi,k), 0\},$$

where $v_P(p;\theta)$ and $v_E(f;\theta,\phi,k)$ denote the conditional indirect utilities of making a purchase and evading payment, respectively. The conditional indirect utilities depend on the relevant prices and the consumer's type; in addition, the notation $v_E(f;\theta,\phi,k)$ captures the dependence of the utility of a payment evader on the belief about the detection probability and the cost of evading payment. For convenience, we normalize the utility of the outside option to zero. We impose the following assumption:

Assumption 1 (Indirect Utility). *(i) The function $v_E(f;\theta,\phi,k)$ is increasing in θ and there is $\underline{\theta} \in [0,\infty)$ such that $v_E(f;\underline{\theta},\phi,k) = 0$. (ii) The difference $v_P(p;\theta) - v_E(f;\theta,\phi,k)$ is increasing in θ and there exists $\overline{\theta} \in [\underline{\theta},\infty)$ satisfying $v_P(p;\overline{\theta}) = v_E(f;\overline{\theta},\phi,k) > 0$.*

Assumption 1 assures that consumers self-select into one of three segments. The type $\overline{\theta}(p,f;\phi,k)$ denotes the consumer who is indifferent between purchasing and evading

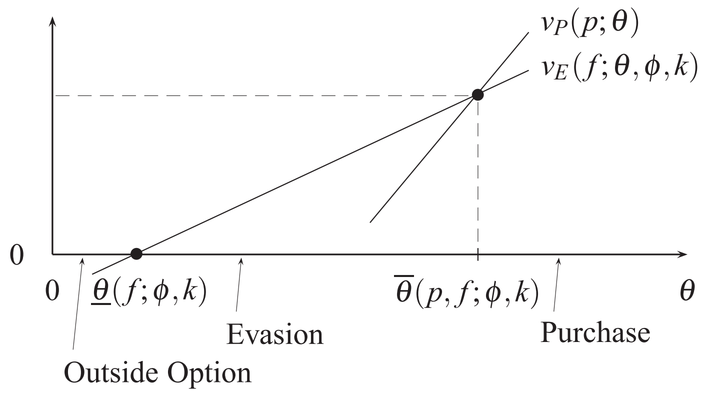


Figure 1: Cut-off Values and Demand Segments.

payment, and consumers with type $\theta \geq \overline{\theta}(p, f;\phi,k)$ purchase the product. The consumer who is indifferent between evading payment and choosing the outside option has type $\underline{\theta}(f;\phi,k)$, and consumers with type $\theta \leq \underline{\theta}(f;\phi,k)$ forgo consumption. Consequently, the remaining consumers with a type θ below $\overline{\theta}(p, f;\phi,k)$ but above $\underline{\theta}(f;\phi,k)$ evade payment, as illustrated in Figure 1. Observe that an increasing utility difference in θ means that the consumers who evade payment suffer from a perceived quality degradation (Yaniv 2009, Belleflamme and Peitz 2012).

The size of each demand segment is determined by the cut-off values $\underline{\theta}(f;\phi,k)$ and $\overline{\theta}(p, f;\phi,k)$, accounting for the distribution of consumer types in the population. From Assumption 1, the demand of paying consumers is given by

$$\begin{aligned} D(p, f;\phi,k) &= N \int_{\overline{\theta}(p,f;\phi,k)}^{+\infty} g(\theta)d\theta \\ &= N[1-G(\overline{\theta}(p, f;\phi,k))]. \end{aligned} \tag{1}$$

The demand of paying consumers depends on the price p and the fine f and reflects the consumers' choice between purchasing and evading payment. In addition, the demand in (1) is affected by the consumers' belief about the detection probability and the cost of evading payment. Similarly, the demand for the outside option can be expressed as

$$\begin{aligned} X(f;\phi,k) &= N \int_{0}^{\underline{\theta}(f;\phi,k)} g(\theta)d\theta \\ &= N[G(\underline{\theta}(f;\phi,k))]. \end{aligned} \tag{2}$$

Notice that demand for the outside option depends on the fine but not on the price, since it reflects the consumers' choice between evading payment and the outside option. We define payment evasion as follows:

Definition 1 (Payment Evasion). *The demand of consumers who evade payment is given by* $E(p, f; \phi, k) = N - D(p, f; \phi, k) - X(f; \phi, k)$*.*

Definition 1 shows that payment evasion is endogenously determined by the interplay of the choices made by the firm and by consumers. Importantly, the presence of payment evaders allows the firm to price-discriminate by selling a product to paying consumers and payment evaders at different prices. Since purchasing and evading payment are substitutes, the demands of paying consumers and payment evaders are interdependent.

3 Managing Payment Evasion

In this section, we first study optimal pricing. We then analyze how changes in binding maximum admissible fines affect pricing and payment evasion. Finally, we provide an example to illustrate. To facilitate exposition, we have relegated proofs to Appendix A.

3.1 Optimal Pricing

When some consumers evade payment, the firm can generate profit from two segments: paying consumers and payment evaders. The firm chooses the price and the fine to maximize its (expected) profit from the two segments:

$$\begin{aligned} \max_{p,f} \quad & \Pi(p, f) = (p-c)D(p, f) + (\pi f - c)E(p, f) - F - F_\pi \qquad (3) \\ \text{s.t.} \quad & p \geq 0 \\ & 0 \leq f \leq \bar{f}, \end{aligned}$$

where $E(p, f) = N - D(p, f) - X(f)$ by Definition 1. To put additional structure on this problem, we impose the following assumption:[8]

Assumption 2 (Regularity Conditions). *The profit function* $\Pi(p, f)$ *is strictly concave. The demand of paying consumers satisfies* $\frac{\partial}{\partial p}D(p, f) < 0$ *and* $\frac{\partial}{\partial f}D(p, f) > 0$*, and the demand for the outside option satisfies* $X'(f) > 0$*.*

[8]We assume that the total fixed cost does not exceed the product market profit. Hence, the fixed cost does not change the analysis and can be omitted.

Assumption 2 ensures that the objective function has a unique global constrained maximizer and clarifies the impact of the endogenous variables on the demand functions.[9] The necessary and sufficient Kuhn-Tucker conditions for profit maximization are:

$$D(p^*, f^*) + (p^* - \pi f^*)\frac{\partial D(p^*, f^*)}{\partial p} = -\lambda_1, \tag{4}$$

$$(p^* - \pi f^*)\frac{\partial D(p^*, f^*)}{\partial f} + \pi(N - D(p^*, f^*) - X(f^*)) - (\pi f^* - c)X'(f^*) = -\lambda_2 + \lambda_3, \tag{5}$$

$$\lambda_1 p^* = 0, \quad \lambda_2 f^* = 0, \quad \text{and} \quad \lambda_3(f^* - \bar{f}) = 0,$$

where the λs are nonnegative multipliers associated with the inequality constraints.

The first-order conditions have intuitive interpretations. First, a marginal increase in the price p has the usual impact on the revenue from paying consumers, distorted upwards by the factor $-\pi f(\partial D/\partial p)$. This distortion arises because some paying consumers are diverted to the segment of payment evaders who can be fined in expectation, which in turn dampens the revenue reduction on the inframarginal units. Second, a marginal increase in the fine f affects the revenue from expected fines, which is distorted upwards by the factor $p(\partial D/\partial f)$ since some payment evaders are induced to pay. In addition, the first-order conditions show that a marginal increase in p does not affect costs while a marginal increase in f does because some payment evaders are deterred and forgo consumption. We derive the following result.

Proposition 1 (Pricing). *The profit-maximizing expected fine πf^* exceeds the unit cost c and the optimal price p^* satisfies*

$$\frac{p^* - c}{p^*} = \frac{1}{\varepsilon_p} + \frac{\pi f^* - c}{p^*}, \tag{6}$$

where $\varepsilon_p \equiv -(\partial D/\partial p)(p/D)$ denotes the price elasticity of demand.

Proposition 1 shows that the relative profit margin—the Lerner index—exceeds the inverse price elasticity of demand, such that regular consumers "overpay" due to the presence of payment evaders.[10] This is a consequence of the fact that an increase in

[9] We follow the standard approach and impose the assumptions on the impact of p and f directly on the relevant demand functions D and X. An alternative approach would be to state these assumptions in terms of the properties of the underlying indirect utility functions v_P and v_E introduced in Assumption 1. Appendix B establishes the relationship between the two approaches.

[10] This result is reminiscent of standard multiproduct monopoly pricing with interdependent demands when the products are substitutes. See, for instance, Tirole (1988, p. 69).

the price diverts some paying consumers to the segment of payment evaders. Thus, the potential to generate revenue from diverted consumers creates an incentive for the firm to raise the price above the level that would otherwise be optimal. Proposition 1 also shows that the self-selection of individuals into regular consumers and payment evaders leads to a form of second-degree price discrimination (Phlips 1986, Anderson and Dana 2009) in which regular consumers pay a higher price than payment evaders pay in expectation ($p^* > \pi f^*$). The firm can price discriminate because evading payment involves a perceived quality degradation even though the product is physically homogenous.

3.2 Changes in Maximum Admissible Fines

This section studies how changes in binding maximum admissible fines affect the firm's pricing decisions and payment evasion by consumers.[11] Maximum admissible fines are binding when changes in $\bar{f}$ have little impact on the demand for the outside option, that is, when $X'(\bar{f})$ is sufficiently small (see proof of Proposition 1). Put differently, this requires that relatively few consumers are induced to choose the outside option in response to an increase in $\bar{f}$.

Proposition 2 (Maximum Fine). *(i) If $\partial^2 D/(\partial f \partial p) \geq 0$, the constrained optimal price $p^*(\bar{f})$ increases in the maximum admissible fine $\bar{f}$. (ii) The impact of an increase in $\bar{f}$ on payment evasion, $E^*(\bar{f})$, is ambiguous.*

Proposition 2 shows that when the firm is constrained by legal restrictions in setting the optimal fine, relaxing this constraint results in a higher price (and a higher expected fine). The intuition for this result is similar to the one underlying Proposition 1. Because the expected fine for payment evaders increases, it is optimal for the firm to raise the price for paying consumers as well. In addition, Proposition 2 shows that a higher fine does not necessarily reduce payment evasion. To understand this result, observe that $E^*(\bar{f}) \equiv E(p^*(\bar{f}), \bar{f})$. Even though a higher $\bar{f}$ has a dampening effect on payment evasion, the overall impact on payment evasion is generally ambiguous due to the upward pressure on the purchase price. However, if the resulting price increase is not too large, the direct effect dominates the price-mediated effect, and the higher fine has the expected effect on payment evasion.

3.3 Example

We consider a market with a unit mass of consumers who have correct beliefs about the detection probability ($\phi = \pi$). Consumer types θ are drawn independently from a

[11] Evidently, changes in $\bar{f}$ do not affect the choices made by the firm and consumers if the maximum admissible fine is not binding.

uniform distribution over the interval $[0,1]$, and the conditional indirect utility functions are given by $v_P(p;\theta) = \theta s_P - p$ and $v_E(f;\theta,\pi,k) = \theta s_E - \pi f - k$. Assumption 1 requires that $s_P > s_E$ and imposes that $\underline{\theta}(f) \leq \overline{\theta}(p,f)$, thereby restricting the evasion cost to be sufficiently small in order for payment evasion to occur:

$$k \leq \frac{ps_E - \pi f s_P}{s_P} \equiv \bar{k}.$$

The demand of paying consumers and the demand for the outside option are given by

$$D(p,f) = 1 - \frac{p - \pi f - k}{s_P - s_E} \quad \text{and} \quad X(f) = \frac{\pi f + k}{s_E},$$

respectively, and payment evasion can be derived as

$$E(p,f) = \frac{ps_E - (\pi f + k)s_P}{(s_P - s_E)s_E}.$$

The next result illustrates Propositions 1 and 2. To ensure that $\bar{k}$ is a positive number, we assume that $\bar{f} < \frac{s_E}{2\pi}$.

Corollary 1. *Suppose that* $\bar{f} < \frac{s_E}{2\pi}$ *and* $k \leq \frac{(s_P - s_E)(s_E - 2\pi\bar{f})}{2s_P - s_E}$. *Then, (i) the optimal price and fine are given by*

$$p^* = \pi\bar{f} + \frac{s_P - s_E + k}{2} \quad \textit{and} \quad f^* = \bar{f};$$

(ii) the price p^* *increases in the maximum fine* $\bar{f}$*; and (iii) payment evasion is given by*

$$E^*(\bar{f}) = \frac{1}{2} - \frac{\pi\bar{f}}{s_E} - \frac{(2s_P - s_E)k}{2(s_P - s_E)s_E}$$

and decreases in $\bar{f}$.

Corollary 1 is useful for a comparison to the standard monopoly model. If the cost of evading payment is prohibitively high ($k \geq \bar{k}$), nonpaying consumers are automatically excluded by pricing alone ($E^*(\bar{f}) = 0$). If the cost of evading payment is low ($k < \bar{k}$), payment evasion occurs ($E^*(\bar{f}) > 0$) and is fined in expectation, thus making it a source of profit for the firm.

4 Extensions

We consider two extensions in which the firm has additional tools to deal with payment evasion. First, we allow the firm to choose the detection probability through costly effort. Second, we allow the firm to manipulate the evasion cost by investing in technological protection.

4.1 Endogenous Detection Probability

To endogenize the choice of the detection technology, we now assume that the firm can influence both the detection probability and the cost of the detection technology through its choice of (costly) control effort. To this end, we extend our model to a setting in which the firm makes sequential decisions. Specifically, we consider the following two-stage game. In stage 1, the firm chooses the price p and the fine f, subject to the constraints $p \geq 0$ and $0 \leq f \leq \bar{f}$. In stage 2, the firm chooses the effort $e \geq \underline{e}$, where $\underline{e}$ is the lowest admissible effort that satisfies the condition $\pi(\underline{e})\bar{f} \geq c$ and thus gives rise to a sufficiently effective detection technology. The control effort determines the detection probability, $\pi(e)$, and the cost of the technology, $F_\pi(e)$. This timeline captures a business environment in which the control effort can be varied in the short run while the price and the fine are chosen in the long run.

The firm's (short run) effort-choice problem is

$$\max_{e \geq \underline{e}} \quad \Pi(e;p,f) = (p-c)D(p,f) + (\pi(e)f - c)E(p,f) - F - F_\pi(e),$$

where we assume that $\pi(e)$ is strictly concave with $\pi(0) = 0$ and $\pi(+\infty) = 1$ and that the effort cost, $F_\pi(e)$, is strictly convex with $F_\pi(0) = 0$. Using backward induction, we derive the following result.

Proposition 3 (Effort Choice). *Denote by $\varepsilon_p \equiv -(\partial D/\partial p)(p/D)$ the price elasticity of demand and by $\varepsilon_f \equiv -(\partial E/\partial f)(f/E)$ the elasticity of payment evasion with respect to the fine f. (i) At the constrained optimum, the optimal price $p^*(\bar{f})$ is a solution to*

$$\frac{p^*-c}{p^*} = \frac{1}{\varepsilon_p} + \frac{\pi(e^*)\bar{f} - c}{p^*}, \tag{7}$$

and the implied optimal effort $e^*(\bar{f})$ solves $\pi'(e^*)\bar{f}E(p^*,\bar{f}) - F'_\pi(e^*) = 0$. (ii) Suppose that $\partial^2 D/(\partial f \partial p) \geq 0$. Then, the constrained optimal price $p^*(\bar{f})$ increases in $\bar{f}$ and the optimal effort $e^*(\bar{f})$ decreases (increases) in $\bar{f}$ if $\varepsilon_f > 1$ ($\varepsilon_f < 1$).

This result shows that the pricing rule and its comparative statics (Propositions 1 and 2, respectively) generalize naturally to a setting in which the probability of detection is endogenous. In addition, Proposition 3 shows that the comparative statics with respect to $\bar{f}$ are similar to the predictions in the law and economics literature (cf. Polinsky and Shavell 2000): Costly effort decreases in response to an increase in the maximum admissible fine provided that payment evasion is sufficiently responsive to a change in $\bar{f}$. Intuitively, the same level of deterrence can be attained with a lower level of effort, which results in both a smaller probability of detection and a lower enforcement cost.

4.2 Endogenous Technological Protection

We now assume that the firm can invest in technological protection to raise the evasion cost borne by consumers before it chooses the price and the fine.[12] Again, we consider a two-stage game. In stage 1, the firm commits to a level of technological protection that is reflected by the evasion cost k. Establishing the level of protection k requires an investment of $F_k(k)$. In stage 2, the firm chooses the price p and the fine f subject to two constraints: $p \geq 0$ and $0 \leq f \leq \bar{f}$. Specifically, the firm's choice of technological protection solves

$$\max_{k \geq 0} \quad \Pi(k) = (p^*(\bar{f},k) - c)D^*(\bar{f},k) + (\pi \bar{f} - c)E^*(\bar{f},k) - F - F_k(k), \tag{8}$$

where $p^*(\bar{f},k)$, $D^*(\bar{f},k) \equiv D(p^*(\bar{f},k),\bar{f})$, and $E^*(\bar{f},k) \equiv E(p^*(\bar{f},k),\bar{f})$ follow from the second-stage problem described in Section 3. We assume that the cost of the protection technology, $F_k(k)$, is strictly convex with $F_k(0) = 0$.

Clearly, the optimal choice of technological protection depends on the functional form of the cost function $F_k(k)$. Now, if the solution to problem (8), denoted as k^*, exceeds $\bar{k}$, a level of k so high that evading payment is "too costly," payment evasion is prevented endogenously by means of technological protection. For $k^* < \bar{k}$, there remains some level of payment evasion, which is detected with probability π.

5 Empirical Evidence

In this section, we apply our model to the data and estimate payment evasion faced by a large Swiss public transportation operator. In addition, we investigate how payment evasion is affected by an exogenous increase in the maximum admissible fine.

5.1 Transportation Operator

The *Zurich Transport Network* (ZVV) is a public transportation operator that coordinates more than 50 service providers and offers railroad, bus, tram, and boat services in Zurich and its surrounding regions.[13] The operator is a monopolist that carries about 570 million passengers a year and the transportation network is set up as an "open-access" system that allows passengers to board any form of transport without prior ticket inspection.

The ZVV chooses ticket prices and fines for payment evaders. The fines are limited by maximums prescribed by the national industry association for public transportation

[12] Examples include installing anti-shoplifting devices and use of digital rights management systems.

[13] The ZVV is owned by participating municipalities and the Canton of Zurich, a member state of the federal state of Switzerland.

Table 1: Fines for Traveling without a Valid Ticket.

	Before June 1, 2011	After June 1, 2011	Change
First offense	80	100	25.0%
Second offense*	120	140	16.7%
Three or more offenses*	150	170	13.3%

Notes: Fines are in Swiss Francs (CHF) and consist of a surcharge for traveling without a valid ticket and a flat fare amount to cover the lost revenue. *Higher fines apply to violations within two years of settlement of the last offense.

(*Verband öffentlicher Verkehr*, VöV). Specifically, the ZVV imposes the following fines: Passengers who fail to present a valid ticket must prove their identity and pay CHF 80 (about $75) for a first offense. The fine for the second offense is CHF 120 (about $115). For the third and any subsequent offenses within two years, the fine increases to CHF 150 (about $145). Table 1 summarizes the fines and changes in them on June 1, 2011. Information on the fines is prominently posted at all stops, in the entry areas, and on the windows of all means of transport.

The ZVV conducts ticket inspections and collects personal information from payment evaders. This allows the ZVV to identify repeat offenders (who potentially use different operators within the network) and construct the two-year period during which higher fines apply. The personal information includes address, gender, nationality, and date and place of birth. Data privacy laws require the ZVV to delete the records of passengers who have no repeated offenses within two years.

5.2 Passengers

We consider two groups of passengers: Passengers who use the network (the reference group) and detected payment evaders.[14] The characteristics of passengers in the reference group are obtained from a sample constructed from data from the Swiss 2010 census on transportation and mobility.[15] This indirect approach is necessary since the ZVV collects data solely from detected payment evaders. Table 2 provides descriptive statistics for the reference group (labeled 0-group).

The characteristics of payment evaders are obtained from a sample constructed from data provided by the ZVV that covers June 1, 2009, through to May 31, 2013.[16] An

[14] To meaningfully compare the two groups, we removed detected payment evaders who had no permanent address in Switzerland from our sample.

[15] The census, *Mikrozensus Mobilität und Verkehr 2010*, is a representative study compiled by the Swiss Federal Statistical Office (see http://www.bfs.admin.ch).

[16] The data set combines proprietary data on all detected payment evaders obtained from *PostBus Switzerland Ltd* (Region Zurich), the *Verkehrsbetriebe Zürich* (VBZ), and *Swiss Federal Railways* (SBB),

Table 2: Descriptive Statistics for the Consumer Groups.

Variable	Comparison of Groups			Breakdown of E-group by Number of Offenses			
Mean, values in %	0-group	E-group	p-value	1	2-3	4-7	8+
Men	48	57	0.00	55	63	73	75
Age in years (mean)	39	31	0.00	32	29	28	28
Amount in CHF	–	120	–	108	155	191	190
Other violations (0/1)	–	1.1	–	1.1	1.2	1.4	0.6
Sample size	3,734	112,872	–	90,396	18,061	3,337	1,078

Notes: All individuals in the data set had a permanent address in Switzerland. The reference group consists of a representative sample of passengers (0-group), including evaders, and the group of payment evaders (E-group) consists of all pre-June 2010 evaders. The p-value is determined from a two-sample t-test for mean differences between 0-group and E-group. Repeat offenders: 1, 2-3, 4-7, and 8+ offenses by the same individual. Other violations is an indicator of whether payment evasion was associated with some other violation (including attempted escape from ticket inspection or using forged tickets).

important feature of the data set is that it includes information on all detected payment evaders during the sample period. Table 2 provides descriptive statistics for all pre-June 2010 payment evaders (the E-group) and a comparison to the reference group. Our first finding summarizes the insights of this comparison.

Finding 1 (**Payment Evaders**). *Men and young adults are significantly overrepresented among payment evaders relative to the reference group.*

Finding 1 is consistent with previous studies of crime (DiIulio 1996) and shoplifting (Cox et al. 1990), which report a concentration of offenses among young men.

Table 2 offers additional insights. First, the degree of overrepresentation by men and young adults among payment evaders is positively related to the number of offenses. Second, ticket inspections allow the firm to collect an average of CHF 120 from detected payment evaders. This amount includes the fine and additional fees from other violations, including attempted escape from ticket inspection and using forged tickets. Such additional violations are committed by 1.1% of the detected payment evaders.

the three operators that conduct ticket inspections on behalf of the ZVV. Construction of the merged data set was necessary because each operator has only limited access to the data pool to comply with data privacy laws.

Table 3: Quantifying Payment Evasion.

Monthly averages	Before June 1, 2011	After June 1, 2011	Change (%)
Total passengers ($D+E$)	46,751,476	48,411,632	3.6
Checked passengers (C)	645,427	613,049	−5.0
Detection probability ($\hat{\pi}$)	0.0138	0.0127	−8.3
Cheapest ticket price (p)	2.20	2.20	–
Expected fine ($\hat{\pi} f$)			
First offense	1.10	1.27	14.7
Second offense	1.66	1.77	7.0
Three or more offenses	2.07	2.15	4.0
Detected payment evaders ($\tilde{E}$)	8,539	9,169	7.4
Payment evasion ($\hat{E}$)	618,507	724,024	17.1

Notes: The estimated detection probability is equal to the number of detected payment evaders divided by the total number of passengers. Estimated payment evasion is equal to the number of detected payment evaders divided by the estimated detection probability. Expected fines in Swiss francs (CHF) are obtained by multiplying the estimated detection probability by the relevant fine.

5.3 Quantifying Payment Evasion

Ticket inspections are unannounced and random from the perspective of passengers. When ticket inspection agents board a public service vehicle, they require all passengers to present a valid ticket, which rules out statistical discrimination. Passengers who fail to present a valid ticket must prove their identity and provide their personal information. In addition, agents record the number of passengers who are checked in ticket inspections. We use these data to construct an estimate of the detection probability by dividing the number of checked passengers by the total number of passengers (see Table 3).

Finding 2 (Pricing). *Payment evasion is detected with a probability of about 1.3%, which implies that the cheapest ticket price exceeds the relevant expected fines.*

Finding 2 shows that even the lowest available ticket price is higher than any of the expected fines. This result is in line with Proposition 1. This finding allows us to estimate payment evasion by dividing the number of detected payment evaders by the estimated detection probability (see Table 3). The resulting “crime rate,” defined as the fraction of riders who are payment evaders, is estimated to be 1.5%.

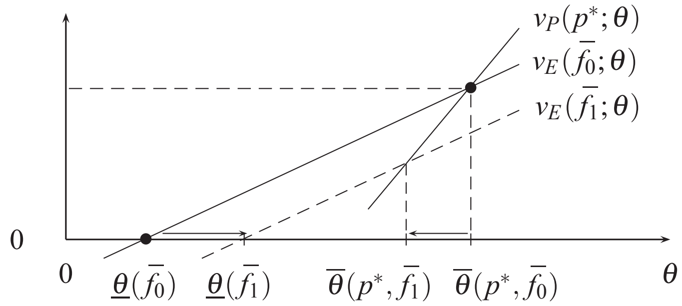


Figure 2: Deterrence Effect of a Higher Fine.

5.4 Increase in Maximum Admissible Fines

The industry association for public transportation increased the maximum admissible fines on June 1, 2011. The ZVV immediately seized the opportunity to increase fines as it consistently charges the maximum fines allowed. Since the ticket prices remained constant during the time of observation, our model predicts that the higher admissible fines will reduce payment evasion (Proposition 2) and therefore—all else equal—the number of detected payment evaders. This leads to the following hypothesis (see Appendix C for proof):

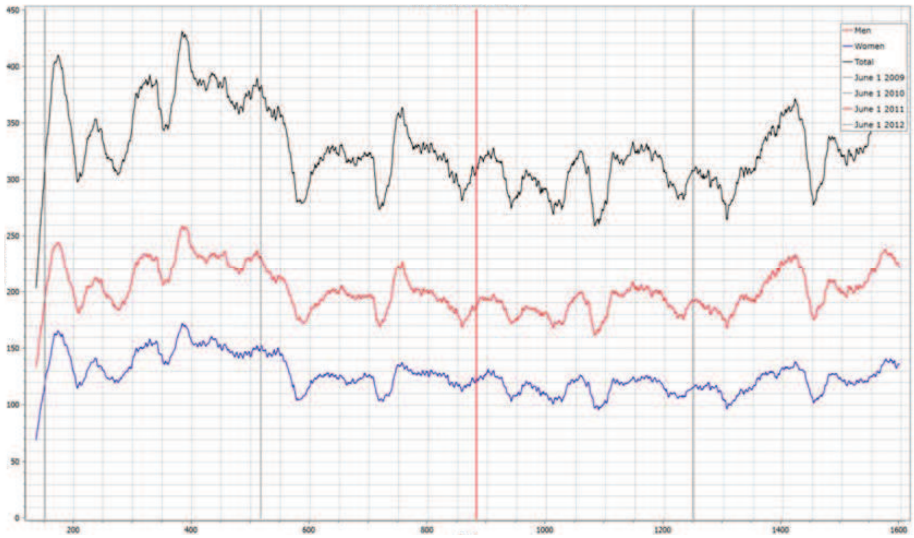
Hypothesis 1 (Deterrence). *If the price is fixed at p_0 and there is an increase in the fine from $\bar{f}_0$ to $\bar{f}_1$, the number of detected payment evaders decreases, and the aggregate change can be decomposed into type-specific changes:*

$$\tilde{E}(p_0,\bar{f}_1)-\tilde{E}(p_0,\bar{f}_0)=-\pi N\left[\int_{\overline{\theta}(p_0,\bar{f}_1)}^{\overline{\theta}(p_0,\bar{f}_0)} g(\theta)d\theta+\int_{\underline{\theta}(\bar{f}_0)}^{\underline{\theta}(\bar{f}_1)} g(\theta)d\theta\right].$$

Hypothesis 1 shows how type-specific effects aggregate across payment evaders: Due to the higher fine, some high-type evaders are induced to purchase while some low-type evaders are induced to choose the outside option, as illustrated in Figure 2. Clearly, the reduction in payment evasion depends on the mass of types in the relevant regions of the density function. The next finding summarizes the aggregate impact of a higher fine.

Finding 3 (Fines). *Higher fines are not associated with fewer detected payment evaders.*

Finding 3 is unexpected according to Hypothesis 1 but is consistent with related empirical research showing that enforcement severity alone does not deter gray market incidence (Antia et al. 2006). Figure 3 illustrates the finding by plotting the aggregate number of detected payment evaders over time. Possible explanations for this result are



Notes: Thirty-day moving average of the daily number of detected payment evaders. The sample period covers June 1, 2009, through May 31, 2013.

Figure 3: Number of Detected Payment Evaders in Total and by Gender.

concurrent changes in the detection probability and market size (measured by the total number of passengers) that compensate for any reduction associated with higher fines (see Table 3). The changes in the detection probability and the number of checked passengers suggest that the ZVV seized the opportunity to reduce its costly (unobservable) control effort in exchange for higher fines, as predicted by Proposition 3.

5.5 Distinguishing Payment Evaders

Finally, we exploit the data on repeat offenses to distinguish groups of payment evaders. Our empirical strategy builds on the assumption that unobservable consumer heterogeneity leads to heterogeneity in observable choices (see Section 2). We thus look for differences in individual offense histories to construct these groups of payment evaders and follow their offenses over time.

In a first step, we let payment evaders self-select into groups based on their individual offense histories. The self-selection period runs from June 1, 2009, through May 31, 2010. The choice of this period ensures that the selection process is plausibly unaffected by the change in maximum admissible fines. To have a sufficiently large number of observations in each group, we assign detected payment evaders to one of four groups: one offense (1), two and three offenses (2-3), four to seven offenses (4-7), and eight or more offenses (8+). Then, to meaningfully assess the impact of the increase in the

Notes: Thirty-day moving average of the number of detected payment evaders by group divided by the number of members per group. The sample period covers June 1, 2010, through May 31, 2013. The data covering June 1, 2009, through May 31, 2010, are used to let payment evaders self-select into subgroups of types.

Figure 4: Normalized Number of Detected Payment Evaders by Group.

fines, we take into account that the composition of the groups differs by (exogenous) characteristics, as documented in Table 2. To eliminate the effect of these differences in characteristics, we use propensity score weighting (DiNardo et al. 1996). Reweighting is performed such that the distribution of all payment evaders is taken as the reference distribution, and the individuals in each offense group are reweighted accordingly.[17] In a third step, using the reweighted observations, we follow the groups of pre-June-2010 offenders over time. Specifically, we count the number of detected payment evaders in each group after June 1, 2010, and normalize the count data by the respective size of the reference group. This yields the group-specific offense probabilities plotted in Figure 4, which give rise to the following finding.

Finding 4 (Evader Groups). *The groups of payment evaders exhibit systematic differences in offense probabilities.*

This result implies that the payment evaders in each group indeed differ in unobservables that are related to individual offense histories. It thus provides indirect evidence that payment evaders are heterogenous in type, which is consistent with our model of payment evasion.

[17]This approach is in the spirit of Horvitz and Thompson (1952). See Appendix C for details.

6 Conclusion

We have examined endogenous payment evasion in a model in which the firm can charge a price to paying consumers and impose a fine on detected payment evaders. In addition, we have provided empirical evidence on payment evasion using data from fare dodging on public transportation.

We have derived three key results from our theoretical analysis. First, paying consumers "overpay" because the firm charges a higher price than it would in the absence of payment evaders. Specifically, the presence of payment evaders leads to a form of second-degree price discrimination in which the purchase price exceeds the expected fine for payment evasion. Second, the impact of increases in binding maximum admissible fines on payment evasion is generally ambiguous, because such increases have a negative direct effect and a positive price-mediated effect on payment evasion. Third, the result on price discrimination generalizes naturally to a setting in which the firm can endogenously choose the detection probability.

Evidence from the empirical analysis supports our theoretical finding. We constructed empirical counterparts to the relevant quantities in our theoretical model and explained why the increase in the maximum admissible fines is not associated with a reduction in payment evasion. In addition, we found indirect evidence that payment evaders are heterogenous in type.

This research has important implications for managing payment evasion. Firms that face payment evasion should manage it using prices and fines rather than fighting it using technological protection alone. Our work also shows that pricing decisions alone do not suffice to manage payment evasion; it is the interplay with the detection technology and the cost of evasion that determines the deterrence level and hence the expected fine for evading payment. Another insight from this study is that profiling young men could help to reduce payment evasion in public transportation.

Our analysis suggests several avenues for future research. First, one could generalize our analysis to a fully dynamic setting in which consumers repeatedly decide whether to evade payment. Second, one could extend the analysis to allow for competition among firms to study the role of payment evasion for nonprice competition. We hope to address these issues in future research.

Appendix A Proofs

Proof of Proposition 1. The proof uses a two-step argument. (i) By Assumption 1, $D > 0$, and by Assumption 2, $\partial D/\partial p < 0$. Then, if $p^* \leq \pi f^*$, (4) leads to a contradiction since $\lambda_1 \geq 0$. Hence, at the optimum, we must have that $p^* > \pi f^*$ and $\lambda_1 = 0$. Consequently, (4) can be rearranged as

$$\frac{p^* - c}{p^*} = \frac{1}{\varepsilon_p} + \frac{\pi f^* - c}{p^*}.$$

(ii) By Assumption 2, $\partial D/\partial f > 0$ and $X' > 0$. Now suppose that $f^* = 0$ and thus that $\lambda_3 = 0$. Then, (5) leads to a contradiction, implying that f^* is strictly positive. Therefore, at the optimum, either $\lambda_2 = 0$ (corner solution) or both $\lambda_2 = 0$ and $\lambda_3 = 0$ (interior solution). Now, if $f^* = \bar{f}$ and thus $\lambda_2 = 0$, (5) can be written as

$$\begin{aligned}(p^* - \pi \bar{f})\frac{\partial D(p^*, \bar{f})}{\partial f} + \pi(N - D(p^*, \bar{f}) - X(\bar{f})) \\ -(\pi \bar{f} - c)X'(\bar{f}) \quad &= \quad \lambda_3 \geq 0.\end{aligned}$$

Since $\pi \bar{f} - c > 0$ by assumption, $p^* > 0$ and $f^* = \bar{f}$ if

$$X'(\bar{f}) \leq \frac{(p^* - \pi \bar{f})\frac{\partial D(p^*, \bar{f})}{\partial f} + \pi(N - D(p^*, \bar{f}) - X(\bar{f}))}{\pi f - c}.$$

An interior solution $f^* \in (0, \bar{f})$ exists if

$$X'(f^*) \geq \frac{(p^* - \pi f^*)\frac{\partial D(p^*, f^*)}{\partial f} + \pi(N - D(p^*, f^*) - X(f^*))}{\pi f^* - c},$$

and hence $\pi f^* > c$. □

Proof of Proposition 2. If $f^* = \bar{f}$, $p^*(\bar{f})$ is determined by (4). (i) The comparative statics effect of $\bar{f}$ on the optimal price $p^*(\bar{f})$ is readily determined by applying the implicit function theorem to the first-order condition in (4), evaluated at $\bar{f}$:

$$\frac{dp^*(\bar{f})}{df} = -\frac{\frac{\partial D}{\partial f} + (p^* - \pi \bar{f})\frac{\partial^2 D}{\partial f \partial p} - \pi \frac{\partial D}{\partial p}}{2\frac{\partial D}{\partial p} + (p^* - \pi \bar{f})\frac{\partial^2 D}{\partial p^2}}. \tag{A.1}$$

From Proposition 1, we have that $p^* - \pi \bar{f} > 0$. Clearly, the numerator of (A.1) is positive using the properties of D and the denominator is negative by the concavity of the objective function. Hence, $p^*(\bar{f})$ increases in $\bar{f}$. (ii) At the optimum, payment evasion is given by $E^*(\bar{f}) \equiv E(p^*(\bar{f}), \bar{f})$. Totally differentiating this expression produces

$$\frac{dE^*(\bar{f})}{df} = \frac{\partial E}{\partial p}\frac{dp^*(\bar{f})}{df} + \frac{\partial E}{\partial f}.$$

Definition 1, the properties of D and X, and (A.1) immediately imply that the impact of $\bar{f}$ on payment evasion is generally ambiguous. □

Proof of Corollary 1. (i) The firm chooses the optimal price and fine so as to

$$\max_{p,f} \quad \Pi(p,f) = (p-c)\left(1-\frac{p-\pi f-k}{s_P-s_E}\right)+(\pi f-c)\left(\frac{ps_E-(\pi f+k)s_P}{(s_P-s_E)s_E}\right)$$

subject to the constraints $p \geq 0$ and $0 \leq f \leq \bar{f}$. Partially differentiating the profit function with respect to f yields

$$\frac{\partial \Pi(p,f)}{\partial f} = \frac{\pi(2(ps_E-\pi f s_P)+c(s_P-s_E)-ks_P)}{(s_P-s_E)s_E},$$

which is strictly positive for $k < \bar{k}$. This implies that there is no interior solution for f and the optimal price therefore follows from (6). (ii) The result follows by inspection of p^*. (iii) Payment evasion results by substitution, and $E^* \geq 0$ as long as $k < \frac{(s_P-s_E)(s_E-2\pi\bar{f})}{2s_P-s_E}$ (the upper bound for k expresses $\bar{k}$ in terms of the model parameters). Inspection of E^* shows that it decreases in $\bar{f}$. □

Proof of Proposition 3. (i) In the second stage, for a given (p,f), the firm solves

$$\max_{e \geq \underline{e}} \quad \Pi(e;p,f) = (p-c)D(p,f)+(\pi(e)f-c)E(p,f)-F-F_\pi(e).$$

At an interior solution, the optimal effort $e^*(p,f)$ solves

$$\pi'(e^*(p,f))fE(p,f)-F'_\pi(e^*(p,f)) = 0. \tag{A.2}$$

Substituting $e^*(p,f)$ back into the profit function, the firm solves

$$\max_{p,f} \quad \Pi(p,f) = (p-c)D(p,f)+(\pi(e^*(p,f))f-c)E(p,f)-F-F_\pi(e^*(p,f))$$

subject to the constraints $p \geq 0$ and $0 \leq f \leq \bar{f}$ in the first stage. Applying the envelope theorem, the first-order condition for p at the constrained optimum is

$$\frac{\partial \Pi}{\partial p} = D + (p-\pi(e^*)\bar{f})\frac{\partial D}{\partial p} = 0, \tag{A.3}$$

which can be rearranged as (7) using the same logic as in the proof of Proposition 1. Denoting the solution to (A.3) as $p^*(\bar{f})$, the implied optimal effort $e^*(\bar{f}) \equiv e^*(p(\bar{f}),\bar{f})$ follows from (A.2) by substitution. Further substituting the optimal effort level e^* into $\pi(e)$ and $F_\pi(e)$ yields $\pi(e^*)$ and $F_\pi(e^*)$. (ii) Applying the implicit function theorem to (A.3) yields

$$\frac{dp^*}{df} = -\frac{\frac{\partial D}{\partial f}-[\pi'\frac{de^*}{df}\bar{f}+\pi]\frac{\partial D}{\partial p}+(p-\pi\bar{f})\frac{\partial^2 D}{\partial f \partial p}}{[-]}$$

where $[-]$ indicates a negative expression (the negativity follows from the second-order condition). Using Assumption 2, the numerator is positive provided that $\frac{de^*}{df} > 0$ (which is clearly an overly strong condition). Applying the implicit function theorem again, this time to (A.2), produces

$$\begin{aligned}\frac{de^*}{df} &= -\frac{\pi'(e^*)(E(p,f)+f\frac{\partial E(p,f)}{\partial f})}{\pi''(e^*)fE(p,f)-F''_\pi(e^*)} \\ &= -\frac{\pi'(e^*)E(p,f)(1-\varepsilon_f)}{\pi''(e^*)fE(p,f)-F''_\pi(e^*)},\end{aligned}$$

which is positive as long as $\varepsilon_f < 1$. Given the assumed properties of $\pi(e)$ and $F_\pi(e)$, it follows that the detection probability $\pi(e^*)$ and the effort cost $F_\pi(e^*)$ increase in $\overline{f}$. □

Appendix B Linking Preferences and Demand

This appendix links the properties of demand of paying consumers and demand for the outside option to the properties of the underlying conditional indirect utility functions. To simplify the exposition, we suppress the arguments of the functions.

From (1), the demand of paying consumers is $D = N[1 - G(\overline{\theta})]$. This demand decreases in price p provided that

$$\frac{\partial D}{\partial p} = -Ng(\overline{\theta})\frac{\partial \overline{\theta}}{\partial p} < 0$$

where

$$\frac{\partial \overline{\theta}}{\partial p} = -\frac{\frac{\partial}{\partial p}v_P}{\frac{\partial}{\partial \theta}(v_P - v_E)} \tag{B.4}$$

results from applying the implicit function theorem to the indifference condition $v_P(p;\overline{\theta}) = v_E(f;\overline{\theta},\phi)$, which defines $\overline{\theta}$. Since $g(\theta) > 0$ for all θ and since the denominator of the right-hand side of (B.4) is positive by Assumption 1, demand decreases in price p if and only if $\partial v_P/\partial p < 0$, that is, if and only if the indirect utility of obtaining the product with payment decreases in price. The demand of paying consumers increases in the fine f provided that

$$\frac{\partial D}{\partial f} = -Ng(\overline{\theta})\frac{\partial \overline{\theta}}{\partial f} > 0 \tag{B.5}$$

where

$$\frac{\partial \overline{\theta}}{\partial f} = \frac{\frac{\partial}{\partial f}v_E}{\frac{\partial}{\partial \theta}(v_P - v_E)}.$$

Using Assumption 1, the demand of paying consumers increases in the fine f if and only if $\partial v_E/\partial f < 0$, that is, if and only if the indirect utility of obtaining the product by evading payment decreases in the fine.

From (2), demand for the outside option is $X = N[G(\underline{\theta})]$. This demand increases in the fine f provided that

$$\frac{\partial X}{\partial f} = Ng(\underline{\theta})\frac{\partial \underline{\theta}}{\partial f} > 0 \tag{B.6}$$

where

$$\frac{\partial \underline{\theta}}{\partial f} = -\frac{\frac{\partial}{\partial f}v_E}{\frac{\partial}{\partial \theta}v_E} > 0.$$

Using Assumption 1, demand for the outside option increases in f if and only if $\partial v_E/\partial f < 0$. Therefore, we can restate the demand properties in Assumption 2 in terms of the properties of the underlying conditional indirect utility functions as follows.

Proposition 4 (Utility Foundation). *Suppose that the indirect utility functions $v_E(f)$ and $v_P(p)$ decrease in f and p, respectively. Then, the demand of paying consumers satisfies $\frac{\partial}{\partial p}D(p,f) < 0$ and $\frac{\partial}{\partial f}D(p,f) > 0$, and the demand for the outside option satisfies $X'(f) > 0$.*

Appendix C Empirical Analysis

Proof of Hypothesis 1. From the fundamental theorem of calculus, the overall change in payment evasion can be decomposed as

$$\begin{aligned} E(p_0,\bar{f_1}) - E(p_0,\bar{f_0}) &= \int_{\bar{f_0}}^{\bar{f_1}} \frac{\partial E(p_0,f)}{\partial f} df \\ &= -\left[\int_{\bar{f_0}}^{\bar{f_1}} \frac{\partial D(p_0,f)}{\partial f} df + \int_{\bar{f_0}}^{\bar{f_1}} \frac{\partial X(f)}{\partial f} df \right], \end{aligned} \tag{C.1}$$

where the second equality follows from Definition 1. Substituting the integrands in (C.1) with the corresponding expressions in (B.5) and (B.6), the change in payment evasion follows using integration by substitution. Using that $\tilde{E} = \pi E$ by construction, it follows that $\Delta\tilde{E} = \pi\Delta E$. Finally, multiplying (C.1) by π establishes the claim. ☐

Details on Propensity Score Weighting. For each offender group, the estimator is implemented as follows: a) Pool a particular offender group with the group of all offenders (the observations of the particular group will thus appear twice). b) Compute an indicator variable, T_i, which takes a value of one if an observation belongs to the target population and zero when it belongs to the particular offender population under investigation. c) Estimate a binary probit to compute $p_i := P(T_i = 1|X = x_i)$. Covariates in this probit are age, age squared, gender, gender-age interactions, indicators for different groups of foreigners, gender-foreigner interactions, and other violations. A constant term is included as well. d) Let $w_i = (1-p_i)/p_i$ and normalize w_i such that the values sum to one. The mean of y (e.g., the probability of an offense) among this particular group of offenders is then computed as the sum of $w_i y_i$ over all offenders of this group. The estimation results of the probit and the descriptive table show that reweighting successfully balances the covariates.

References

Anderson, Eric T. and James D. Dana (2009), "When Is Price Discrimination Profitable?," *Management Science*, 55(6), 980–89.

Antia, Kersi D., Mark E. Bergen, Shantanu Dutta, and Robert J. Fisher (2006), "How Does Enforcement Deter Gray Market Incidence?," *Journal of Marketing*, 70(1), 92–106.

Becker, Gary S. (1968), "Crime and Punishment: An Economic Approach," *Journal of Political Economy*, 76(2), 169–217.

Belleflamme, Paul and Martin Peitz (2012), "Digital Piracy: Theory," in: Peitz, Martin and Joel Waldfogel (eds.), *The Oxford Handbook of the Digital Economy*, Oxford University Press.

Boyd, Colin, Christine Martini, John Rickard, and Allen Russell (1989), "Fare Evasion and Non-Compliance," *Journal of Transport Economics and Policy*, 23(2), 189–97.

Chellappa Ramnath K. and Shivendu Shivendu (2005), "Managing Piracy: Pricing and Sampling Strategies for Digital Experience Goods in Vertically Segmented Markets," *Information Systems Research*, 16(4), 400–17.

Chen, Yuxin, Oded Koenigsberg, and Z. John Zhang (2013), "Pay-as-You-Wish-Pricing," *mimeo*.

Cox, Dena, Anthongy D. Cox, and George P. Moschis (1990), "When Consumer Behavior Goes Bad: An Investigation of Adolescent Shoplifting," *Journal of Consumer Research*, 17(2), 149–59.

DeAngelo, Gregory and Benjamin Hansen (2014), "Life and Death in the Fast Lane: Police Enforcement and Traffic Fatalities," *American Economic Journal: Economic Policy*, 6(2), 231–57.

Deneckere, Ray and R. Preston McAfee (1996), "Damaged Goods," *Journal of Economics and Management Strategy*, 36(4), 149–47.

DiIulio, John J. (1990), "Help Wanted: Economists, Crime and Public Policy," *Journal of Economic Perspectives*, 10(1), 3–24.

DiNardo, John, Nicole M. Fortin, and Thomas Lemieux (1996), "Labor Market Institutions and the Distribution of Wages, 1973-1992: A Semiparametric Approach," *Econometrica*, 64(3), 1001-44

DiTella, Rafael and Ernesto Schargrodsky (2004), "Do Police Reduce Crime? Estimates Using the Allocation of Police Forces After a Terrorist Attack," *American Economic Review*, 94(1), 115–33.

Gneezy, Uri and Aldo Rustichini (2000), "A Fine is a Price," *Journal of Legal Studies*, 29(1), 1–18.

Ehrlich, Isaac (1996), "Crime, Punishment, and the Market for Offenses," *Journal of Economic Perspectives*, 10(1), 43–7.

Frontier Economics (2011), “Estimating the Global Economic and Social Impacts of Counterfeiting and Piracy,” retrieved from http://www.iccwbo.org/Data/Documents/Bascap/Global-Impacts-Study-Full-Report/

Hirshleifer, Jack, Amihai Glazer, and David Hirshleifer (2005), *Price Theory and Applications*, New York, Cambridge University Press, 7th Edition.

Horvitz, Daniel G. and Donovan J. Thompson (1952), “A Generalization of Sampling without Replacement from a Finite Universe,” *Journal of the American Statistical Association* 47(260), 663-85.

Kooreman, Peter (1993), “Fare Evasion as a Result of Expected Utility Maximization,” *Journal of Transport Economics and Policy*, 27(1), 69–74.

Levitt, Steven (1997), “Using Electoral Cycles in Police Hiring to Estimate the Effect of Police on Crime,” *American Economic Review*, 87(3), 270–90.

Mussa, Michael and Shervin Rosen (1978), “Monopoly and Product Quality,” *Journal of Economic Theory*, 18(2), 301–17.

National Association for Shoplifting Prevention (2014), “The Shoplifting Problem in the Nation,” retrieved from http://www.shopliftingprevention.org/what-we-do/learning-resource-center/

Novos, Ian E. and Michael Waldman (1984), “The Effects of Increased Copyright Protection: An Analytical Approach,” *Journal of Political Economy*, 92(2), 235–46.

Oberholzer-Gee, Felix and Koleman Strumpf (2007), “The Effect of File-Sharing on Record Sales: An Empirical Analysis,” *Journal of Political Econonmy* 115(1), 1–42.

Perlman, Yael and Yaacov Ozinci (2014), “Reducing Shoplifting by Investment in Security,” *Journal of the Operational Society*, 65(5), 685–93.

Peukert, Christian, Jörg Claussen, and Tobias Kretschmer (2013), “Piracy and Movie Revenues: Evidence from Megaupload: A Tale of the Long Tail?,” *mimeo*.

Phlips, Louis (1983), *The Economics of Price Discrimination*, Cambridge University Press.

Polinsky, A. Mitchell and Steven Shavell (2000), “The Economic Theory of Public Enforcement of Law,” *Journal of Economic Literature*, 38(1), 45–76.

Ramsey, Frank P. (1927), “A Contribution to the Theory of Taxation,” *Economic Journal*, 37(145), 47–61.

Rob, Rafael and Joel Waldfogel (2007), "Piracy on the Silver Screen," *Journal of Industrial Economics*, 55(3), 379–95.

Rob, Rafael and Joel Waldfogel (2006), "Piracy on the High C's: Music Downloading, Sales Displacement, and Social Welfare in a Sample of College Students," *Journal of Law and Economics*, 49(1), 29–62.

Schmidt, Klaus M., Martin Spann, and Robert Zeithammer, "Pay What You Want as a Marketing Strategy in Monopolistic and Competitive Markets," *Management Science, in press*.

Timoumi, Anne and Anne T. Coughlan (2014), "Wardrobing: Is it Really All That Bad?," *mimeo*.

Tirole, Jean (1988), *The Theory of Industrial Organization*, Cambridge, MA: MIT Press.

Vernik, Dinah A. Devavrat Purohit, and Preyas S. Desai (2011), "Music Downloads and the Flip Side of Digital Rights Management," *Marketing Science*, 30(6), 1011–27.

Waldfogel, Joel (2012), "*Digital Piracy: Empirics*," in: Peitz, Martin and Joel Waldfogel (eds.), *The Oxford Handbook of the Digital Economy*, Oxford University Press, 531–46.

Yaniv, Gideon (2009), "Shoplifting, Monitoring, and Price Determination," *Journal of Socio-Economics*, 38(4), 608–10.

Zentner, Alejandro (2006), "Measuring the Effect of File Sharing on Music Purchases," *Journal of Law and Economics*, 49(1), 63–90.