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Florian Baumann,
Tim Friehe

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Editor:

Prof. Dr. Hans-Theo Normann
Düsseldorf Institute for Competition Economics (DICE)
Phone: +49(0) 211-81-15125, e-mail: normann@dice.hhu.de

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Private Protection Against Crime when Property Value is Private Information

Florian Baumann* Tim Friehe†

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Abstract

This paper analyzes private precautions against crime when the value of the property to be protected is private information. In a framework in which potential criminals can choose between different crime opportunities, we establish that decentralized decision-making by potential victims may lead to suboptimal levels of investment in private protection. This outcome is possible when observable precautions inform potential offenders about the value at risk even when the diversion effect due to private safety measures is taken into account.

Keywords: Crime, displacement, private protection, asymmetric information

JEL-Code: K42

*University of Düsseldorf, Duesseldorf Institute for Competition Economics, Universitätsst. 1, 40225 Düsseldorf, Germany. E-mail: fbaumann@dice.hhu.de.

†University of Bonn, Center for Advanced Studies in Law and Economics, Adenauerallee 24-42, 53113 Bonn, Germany. CESifo, Munich, Germany. E-mail: tim.friehe@uni-bonn.de.

1 Introduction

1.1 Motivation and main results

Crime is a social phenomenon of great importance, adversely affecting many individuals by the minute. Indeed, crime is consistently placed at or near the top of the list of social maladies (see, e.g., Helsley and Strange 1999). In response, potential victims go to considerable length in order to address the crime risk by taking private action. Such private precautions include not only minor expenses such as walking a detour to avoid a dark alley but also sizable investments such as security systems to safeguard the private home, allowing for the empirical judgment that private precaution expenditures are at least of the same order of magnitude as public expenditures (Shavell 1991). Despite its importance for crime control, private protection has received little scholarly attention when compared to public law enforcement (Cook and MacDonald 2010).

We analyze observable private precautions against crime when the value of the property to be protected is private information.[1] Observable private protection against crime is ascribed to possibly deter crime and/or possibly *divert* crime from protected to unprotected potential victims (e.g., Clotfelter 1978, Cook 1986, Shavell 1991). When private precautions against crime divert offenders to other potential victims, private action is associated with a negative externality, implying a private net benefit in excess of the social net benefit. Individuals invest in private protection without taking into account the adverse consequences for individuals whose crime risk has increased as a result of the investment in precautions against crime, so that *overinvestment* in private precautions results for a given level of crime. In fact, there is empirical evidence for this diversion effect of private precautions against crime. For example, an analysis by the National Highway Traffic Safety Administration (NHTSA 1998) reports that the marking of car parts and the consequent drop in the theft of marked cars corresponded to a rise in theft rates for unmarked cars. Similarly, Priks (2009) establishes that the installation of surveillance cameras in the Stockholm subway displaced crime to the surrounding area. However, there also is empirical evidence to the contrary. For example, Guerette and Bowers (2009) analyzed numerous evaluations of situationally focused crime-prevention projects, concluding that crime

[1] The literature on private action against crime distinguishes observable protection measures such as iron bars on the windows of a house and unobservable protection such as storing valuables in a safe (see, e.g., Shavell 1991). Our analysis is restricted to the case of observable protection measures.

displacement appears to be the exception rather than the rule. The results of our study contribute to an understanding of these contradictory empirical findings.

This paper establishes that observable private protection against crime may *attract* crime instead of divert it, and therefore may make it individually optimal to *underinvest* in private action for a given level of crime. The intuition for this finding is that private precautions against crime signal information about the value of the property to be protected. On one hand, private protection makes it harder for criminals to succeed at a given target but, on the other hand, private protection indicates that the given target is particularly worthwhile. Given the two opposing effects, the diversion and the attraction effect, we identify a simple condition for the case in which the latter effect dominates the former (i.e., the case in which private protection attracts criminals and is therefore underinvested in).

The informational set-up we study in this paper is characterized by observable private precautions against crime and unobservable property values, and has been introduced by Lacroix and Marceau (1995). Although it seems to abstract from many important aspects, similar circumstances may be identified in the real-world. For example, there are often neighborhoods where houses are relatively similar from the outside. This is particularly true in modern large-scale construction projects, but also holds in other cases. The potential thief may then wonder about the likely contents of the various houses. In that scenario, a surveillance camera in front of a private house, for example, makes a successful burglary more difficult (and might even make the thief turn to another property), but also indicates that valuable goods are being protected by homeowners. It is this trade-off that our study focuses on.

Our central result is derived in a setting in which potential victims differ in the level of property value that is at risk of crime. The probability that offenders find a suitable target to attempt theft is determined by a function that takes into account both the number of thieves that focus on the same subgroup of potential victims and the number of potential victims in that subgroup. In our benchmark scenario, the value of property is observable. As a result, offenders can perfectly discriminate between potential victims with different property values. For this case, we reproduce the finding of overinvestment in private precautions for a given level of crime. For this assessment, we compare the investment in private action against crime that is individually optimal to the level that is optimal for the collective of potential victims.[2]

[2]The level of precautions that victims would collectively agree on is also considered as a benchmark in Shavell (1991, see also Fn. 9). The objective function we consider when we turn to what private precautions against crime

Next, we consider the fact that property values are usually not easily observable. We suppose that potential victims have private information about their property value, but may signal some information about it by deciding on whether or not to invest in observable private protection against crime. In this scenario, offenders can only discriminate between households with and without private precautions against crime. As a result, thieves update their belief about the expected value of the property upon observing (no) private protection and make an attempt to steal where it seems to be most profitable. In this setting, it may turn out that decentralized decision-making results in fewer potential victims being protected against crime than in the case of centralized decision-making (i.e., that there is underinvestment in precautions against crime). Should the signaling attribute of private precautions not lead to suboptimal levels of investment in private precautions, its existence will provide a counterweight to the gap between private benefits and social benefits that is due to the diversion effect, implying that private decisions are not as disparate from that of the social planner as has been proposed previously.

In the equilibrium of our model, rich individuals invest more in private precautions against crime and are less adversely affected by crime than individuals with low property values. Empirical observations show that households with higher incomes spend more on private protection (Di Tella et al. 2006, Hotte et al. 2009) and are less likely than lower-income households to experience property crime (Bureau of Justice Statistics 2011, Levitt 1999). For instance, based on data of the National Crime Victimization Survey, households with an annual income of $ 15-25 thousand suffered from 32.8 burglary victimizations per thousand households, whereas those with income $ 75 thousand and higher experienced only 16.7 victimizations (Bureau of Justice Statistics 2011). Accordingly, the outcome of our model corresponds with real-life settings.

1.2 Relation to literature

The present study analyzes potential victims' private protection investment when property values vary and are private information, and tests whether resulting levels of investment are aligned with socially optimal ones. For simplicity, we disregard public law enforcement (as in, e.g., Shavell 1991). The interplay between private precautions and public enforcement has been an interest early on (Clotfelter 1977) and continues to be (see, e.g., Grechenig and Kolmar 2011,

are optimal from a social standpoint is the sum of the expected stolen goods and the protection expenditures and thus may be labeled the aggregate burden of crime (as in, e.g., Hotte and van Ypersele 2008).

Lee and Pinto 2009). In this realm, Hylton (1996) has established that potential victims may invest too little in private action, as they externalize part of the increase in social costs via an increase in enforcement costs to the state.

The reasons for departures of private incentives from social ones with respect to investing in private protection against crime include the diversion effect emphasized before. Hui-Wen and Png (1994) establish in a setting in which property values vary and are public information that private security expenditures are likely to divert crime the more easily potential thieves can switch among victims. In our framework, offenders can switch at no cost, which accordingly tilts our model towards the overinvestment result for a given level of crime. Another effect causing a discrepancy between the private optimum and the social optimum stems from the fact that private protection against crime lowers the expected payoff from crime in equilibrium and accordingly confers a benefit to all potential victims (see, e.g., Shavell 1991). By public-goods reasoning, decentralized decision-making likely induces too little investment in private protection. For the most part, our analysis focuses on the case in which the number of offenders is given, thereby eliminating this effect. However, in an extension to our main analysis, we revisit the effect of private protection on the level of crime in our framework. Finally, private and social incentives may differ when society counts criminals' benefits from crime as social benefits. In such a scenario, it may be that potential victims invest excessively in private protection because they fail to internalize a part of the social benefit from the act (see Ben-Shahar and Harel 1995). In the present paper, we focus on theft and do not consider social benefits of crime.[3]

The contribution of the present paper lies in establishing that the informative value of private protection to potential offenders is a possible cause of private investment falling behind the socially optimal level. In our setup, potential victims vary in the value of the property to be protected. Hotte and van Ypersele (2008) and Hotte et al. (2009) similarly discuss the case of heterogeneous victims, but assume that the property value is perfectly observable. We consider these values to be private information, as do Lacroix and Marceau (1995). In their analysis, potential thieves are randomly allocated to potential victims and then decide whether or not to offend. As a consequence, their setting is not permissive regarding the empirically relevant diversion effect. In contrast, offenders in our paper can freely choose between potential targets, enabling us to analyze the relationship between the diversion and the attraction effect.

[3]For a discussion about whether or not to include criminals' benefits from crime, see, for instance, Lewin and Trumbull (1990).

Furthermore, we consider what is optimal for the individual potential victim and the collective of potential victims, while Lacroix and Marceau (1995) focus on decentralized decision-making only.

The structure of the paper is as follows: Section 2 describes the model. Section 3 analyzes the benchmark case in which property values are observable. Section 4 presents the case in which there is asymmetric information regarding the property value. Section 5 considers the fact that decisions regarding private protection influence the share of individuals who opt for crime. Section 6 concludes the study.

2 The model

There is a continuum of risk-neutral potential victims normalized to one. Potential victims own property value y, where $y \in [0, 1]$ is distributed according to the cumulative distribution function $F(y)$. Potential victims may or may not invest in observable private precautions against crime. (No) precaution is associated with costs $p = x > 0$ ($p = 0$).[4] The expected property that a thief can appropriate is given by $s_p y$, $s_p \in (0, 1)$, where the assumption $\Delta s = s_0 - s_x > 0$ mirrors the effectiveness of private protection. In our model, the term s_p may be interpreted as a share (e.g., some valuables are inaccessibly stored in a vault) or as a probability (e.g., the criminal may or may not be successful in disabling the burglar alarm).[5]

There is a mass t of identical risk-neutral thieves who can direct their search for a target to a type θ. Except for Section 5, t will be considered an exogenous parameter.[6] In the case of perfect information, thieves observe the property value and the level of private precaution. Accordingly, every combination of property value and precaution level will be a type of its own (i.e., $\theta \in [0, 1] \times \{0, x\}$), whereas there are only protected and unprotected targets in the case of asymmetric information (i.e., $\theta \in \{0, x\}$). In order to arrive at the expected payoff from

[4] Lacroix and Marceau (1995), among others, similarly consider a binary choice when it comes to victim precaution.

[5] For example, Vollaard and van Ours (2011) indicate that regulation requiring burglary-proof windows and doors for newly built homes have led to a reduction in burglary risk of 26% in a study for the Netherlands.

[6] We are interested in the relationship between the diversion and the attraction effect. These aspects come to the fore most clearly when the crime level is fixed. Note that the divergence of private and social benefits due to the consequences of private precaution for the expected payoffs from crime have been studied elsewhere (see, e.g., Shavell 1991).

attempting a theft with a target of type θ, the appropriable expected property value must be discounted by the probability of finding a suitable target, $q_\theta = q(T_\theta, V_\theta) = m(T_\theta, V_\theta)/T_\theta$, where T_θ is the number of thieves focusing on the same type of target and V_θ is the number of potential victims of the given type. In the spirit of the matching function used in labor economics, the function m indicates the total number of encounters between thieves and suitable targets, is increasing in both of its arguments, and is assumed to be linearly homogenous (see, e.g., Petrongolo and Pissarides 2001). The probability of finding a target increases in the number of households and decreases in the number of thieves with the same focus, $\partial q/\partial T < 0 < \partial q/\partial V$ and, in the following, will be approximated by $q_\theta = (T_\theta/V_\theta)^{-\alpha}$ with $\alpha \in (0, 1)$. Accordingly, q increases at a decreasing rate with the number of potential victims of a given type and decreases at a diminishing rate with the number of thieves. Given that we abstract from public law enforcement, thieves who focus on targets of type θ bear only opportunity costs that result from forfeiting the possibility of focusing on other target types.

The timing of the model is as follows: (1) Potential victims determine whether or not to invest in private protection against crime. (2) Thieves determine which type of household to target, and (3) uncertainty resolves and payoffs realize.

3 Benchmark: Perfect information

In this section, we analyze the case in which the value of property is public information. The findings will primarily be useful as a benchmark for the results derived in the section in which there is asymmetric information about the value of property. First, we derive the equilibrium under decentralized decision-making. Next, we consider what is collectively optimal for potential victims given the way thieves decide about worthwhile targets, which allows us to identify potential deviations between the private and the collective choice.

3.1 Decentralized decision-making

In Stage 2, after decisions about private protection by potential victims have been made in Stage 1, potential thieves can perfectly discriminate between the different target types consisting of the property value at risk and the private precaution expenditures sunk. In equilibrium, it must hold that the criminal opportunity represented by any type $\theta \in [0, 1] \times \{0, x\}$ yields the same expected payoff k for a thief. Otherwise, potential thieves would switch to target groups where expected payoffs are higher, causing the expected payoff in question to fall and other payoffs to increase via the congestion effect immanent in the function q. Consequently, we get the following results at Stage 2:

$$t(\theta)^{-\alpha} s_0 y = k \; \forall \; \theta \text{ with } p = 0 \tag{1}$$

$$t(\theta)^{-\alpha} s_x y = k \; \forall \; \theta \text{ with } p = x, \tag{2}$$

where $t(\theta)$ is the number of thieves focussing on potential victims of type $\theta = (y, p)$, and k indicates expected benefits for a thief which are equalized across target types. The number of thieves then follows as

$$t(\theta) = \left(\frac{s_0 y}{k}\right)^{1/\alpha} \; \forall \; \theta \text{ with } p = 0 \tag{3}$$

$$t(\theta) = \left(\frac{s_x y}{k}\right)^{1/\alpha} \; \forall \; \theta \text{ with } p = x \tag{4}$$

We now turn to the private precaution measures determined by potential victims in Stage 1, and show that there is a critical level for the property value such that private protection expenditures will only be made by potential victims with property values above this threshold. A potential victim will invest in private protection if doing so implies a reduction in expected costs, where expected costs consist of the sum of expected stolen property value and precaution costs. That is, private precaution against crime is chosen by a potential victim with property value y if

$$t(y,0)^{1-\alpha} s_0 y \geq t(y,x)^{1-\alpha} s_x y + x \tag{5}$$

where the left-hand side is expected costs when he does not invest in precautions against crime, and the right-hand side represents expected costs conditional on investing in protection. Inserting the expressions for the number of thieves derived above, (3) and (4), we obtain

$$y \geq \left(\frac{x}{s_0^{1/\alpha} - s_x^{1/\alpha}}\right)^{\alpha} k^{1-\alpha} = y_c \tag{6}$$

The critical property level y_c is such that all potential victims with (weakly) higher property values will choose precautions against crime, whereas all potential victims with property values lower than y_c choose not to invest in precaution. Intuitively, fewer property owners will invest in private protection (i.e., y_c is higher), the more expensive or the less effective (as measured by a lower Δs) it is.

Given this result in Stage 1 of our game, in equilibrium we can describe victim types solely by using property value y, because $y < y_c$ ($y \geq y_c$) implies $p = 0$ ($p = x$) and thereby is a shortcut for type θ. From (3) and (4), we deduce that the number of potential thieves who focus on a target generally increases with the property value y, counteracting the increase in the property value as regards the expected payoff for the criminal. In addition, there is a discontinuity at $y = y_c$ that follows so as to compensate for the differential Δs such that $t(y_c - \epsilon) > t(y_c)$.

In equilibrium, it must hold that thieves who attempt to steal property values less than the critical level and those who focus on higher property values sum up to the total number of thieves.

$$t = \int_0^{y_c} \left(\frac{s_0 y}{k}\right)^{1/\alpha} dF(y) + \int_{y_c}^1 \left(\frac{s_x y}{k}\right)^{1/\alpha} dF(y) \tag{7}$$

This equation describes a relationship between the expected payoff k and the share of protected property owners defined by y_c.

$$\frac{dk}{dy_c} = \alpha \frac{k^{(\alpha-1)/\alpha} y_c^{1/\alpha} f(y_c)[s_0^{1/\alpha} - s_x^{1/\alpha}]}{t} > 0 \tag{8}$$

Intuitively, the expected payoff from theft increases when fewer property owners are protected (i.e., when y_c increases). However, given an exogenous t, this should not be misinterpreted as a decrease in deterrence. In contrast, from (6), private protection is rated as less worthy of investment the higher k, which from (7) is equivalent to a lower number of thieves t and accordingly a lower rate of victimization.

The equilibrium is formally established by simultaneously solving for the values of k and y_c^* from (6) and (7).

3.2 Centralized decision-making

It is now assumed that potential victims seek to collectively minimize the losses that the crime risk imposes on the totality of potential victims by choosing the cut-off level y_c that divides protected and unprotected property holders. This will be considered as the socially optimal choice. When doing so, potential victims anticipate how thieves determine which target to focus on. The minimand is expected costs consisting of the expected stolen property value and the precaution expenditures.

$$
\begin{aligned}
\min_{y_c} W_P =& \int_0^{y_c} t(y)^{1-\alpha} s_0 y dF(y) + \int_{y_c}^1 (t(y)^{1-\alpha} s_x y + x) dF(y) \\
=& k^{\frac{\alpha-1}{\alpha}} \left\{ s_0^{1/\alpha} \int_0^{y_c} y^{1/\alpha} dF(y) + s_x^{1/\alpha} \int_{y_c}^1 y^{1/\alpha} dF(y) \right\} + x[1 - F(y_c)] \qquad (9)
\end{aligned}
$$

The collectively optimal level of y_c fulfills

$$
\begin{aligned}
\frac{dW_P}{dy_c} =& \underbrace{k^{\frac{\alpha-1}{\alpha}} f(y_c) \left\{ (s_0 y_c)^{1/\alpha} - (s_x y_c)^{1/\alpha} \right\} - f(y_c) x}_{A} \\
&+ \underbrace{\frac{\alpha - 1}{\alpha} k^{-1/\alpha} \left\{ s_0^{1/\alpha} \int_0^{y_c} y^{1/\alpha} dF(y) + s_x^{1/\alpha} \int_{y_c}^1 y^{1/\alpha} dF(y) \right\} \frac{dk}{dy_c}}_{B} \qquad (10)
\end{aligned}
$$

The total effect of a change in the share of protected potential victims on the level of expected costs borne by all potential victims consists of a direct and an indirect effect. Term A represents the direct effect which is equal to zero at y_c^* as it reflects the calculus of potential victims at the margin. Term B gives the indirect effect via a change in the expected payoff k derived in (8), which influences how thieves are distributed across potential victims as described in (3)-(4).

This allows to derive the following result:

Proposition 1 *Suppose that the number of criminals is given and that information about property values and private precaution against crime is freely available. Then, decentralized investments in precaution are excessive when compared to the social optimum.*

Proof. Term A in (10) is equal to zero at $y_c = y_c^*$. Term B is negative since $\alpha < 1$ and $dk/dy_c > 0$. Taken together, this implies that an increase in the cut-off would lower the sum of expected costs. ■

When potential victims determine whether or not to invest in private protection measures without consulting fellow potential victims, they select to invest to an excessive extent. This is a consequence of the fact that potential victims do not internalize that a reduction in their expected loss of property achieved by taking private action against crime implies that other property holders are exposed to crime to a higher extent. This finding accords with the diversion effect that has been established in the literature and is replicated here for our setup.

4 Asymmetric information

In this section, we analyze the case in which the value of the property is private information. First, we derive the equilibrium under decentralized decision-making. As a next step, we analyze what is collectively optimal for potential victims.

4.1 Decentralized decision-making

When the value of the property is private information, potential thieves in Stage 2 can only distinguish between targets that are protected and those that are unprotected. This implies that types are only defined by their protection status (i.e., that $\theta = p$). Thieves observe that a number of β $(1-\beta)$ potential victims have chosen protection (no protection). For each group of potential targets, thieves form beliefs about the expected property value contingent on the observation of (no) private precautions against crime. In equilibrium, these beliefs, which we denote by $E_0[y]$ as the expected property value for unprotected potential victims and by $E_x[y]$ for protected ones, must be consistent with the protection choices made by potential victims at the first stage.

At Stage 2, the equilibrium distribution of potential thieves must be such as to fulfill

$$\left(\frac{t-t_c}{1-\beta}\right)^{-\alpha} s_0 E_0[y] = \left(\frac{t_c}{\beta}\right)^{-\alpha} s_x E_x[y] \tag{11}$$

according to the argument that thieves switch from one household type to the other one if that equality were not to hold, where t_c $(t-t_c)$ gives the number of potential thieves who focus on (un-)protected targets. When (11) holds, potential thieves are indifferent as to which type of target to focus on.

Next, we turn to Stage 1 at which the investment in private protection against crime is determined by each potential victim. Private protection is worthwhile for a potential victim with property value y when

$$\left(\frac{t-t_c}{1-\beta}\right)^{1-\alpha} s_0 y \geq \left(\frac{t_c}{\beta}\right)^{1-\alpha} s_x y + x \tag{12}$$

The first term on the right-hand (left-hand) side represents the probability that a given (un-)protected potential victim will in fact be victimized. In contrast to the benchmark setting with observable property values, this probability is the same for all different property values in the group of protected properties and for the ones in the group of unprotected properties. With public information on property values, this probability was also conditional on the actual value of the property. Rearranging (12), we obtain

$$y \geq x \left[s_0 \left(\frac{t - t_c}{1 - \beta} \right)^{1-\alpha} - s_x \left(\frac{t_c}{\beta} \right)^{1-\alpha} \right]^{-1} = \tilde{y}_c \tag{13}$$

which indicates that we once again obtain a critical property value $\tilde{y}_c$, because the term in brackets is the same for all households (i.e., independent of y). As a result, all potential victims with a property value higher (lower) than this critical value choose (no) private precaution against crime.

The critical property value $\tilde{y}_c$ implies that $\beta = 1 - F(\tilde{y}_c)$ $(1 - \beta = F(\tilde{y}_c))$ must hold with regard to the share of protected (unprotected) potential victims. The expected property values contingent on the observation of private precaution and no private precaution follow as $E_0[y] = F(\tilde{y}_c)^{-1} \int_0^{\tilde{y}_c} ydF(y)$ and $E_x[y] = (1 - F(\tilde{y}_c))^{-1} \int_{\tilde{y}_c}^1 ydF(y)$, respectively, by the requirement of consistent beliefs formed by thieves. Therefore, potential thieves incorporate that investing in private protection against crime is beneficial only for holders of property with a reasonably high value. In other words, private protection signals that the property value of the property holder is relatively high. From (11) and (13), the equilibrium values for t_c and $\tilde{y}_c$ are established by simultaneously solving

$$\left(\frac{t - t_c}{F(\tilde{y}_c)} \right)^{-\alpha} s_0 E_0[y] = \left(\frac{t_c}{1 - F(\tilde{y}_c)} \right)^{-\alpha} s_x E_x[y] \tag{14}$$

and

$$\tilde{y}_c = x \left[s_0 \left(\frac{t - t_c}{F(\tilde{y}_c} \right)^{1-\alpha} - s_x \left(\frac{t_c}{1 - F(\tilde{y}_c} \right)^{1-\alpha} \right]^{-1} \tag{15}$$

4.2 Centralized decision-making

In this section, we describe how potential victims collectively minimize the losses that crime imposes on them by choosing the cut-off level y_c that determines the share of protected and unprotected property holders. The objective function of potential victims must take into account that thieves act only on the signal obtained from private protection instead of on precaution and property value in concert. This is represented by

$$W_A = \left(\frac{t - t_c}{F(y_c)} \right)^{1-\alpha} s_0 \int_0^{y_c} ydF(y) + \left(\frac{t_c}{1 - F(y_c)} \right)^{1-\alpha} s_x \int_{y_c}^1 ydF(y) + x[1 - F(y_c)] \tag{16}$$

The collectively optimal level of y_c fulfills

$$\frac{dW_A}{dy_c} = \underbrace{f(y_c)\left(\frac{t-t_c}{F(y_c)}\right)^{1-\alpha} s_0 y_c - f(y_c)\left\{\left(\frac{t_c}{1-F(y_c)}\right)^{1-\alpha} s_x y_c + x\right\}}_{A}$$

$$+ \underbrace{f(y_c)(\alpha-1)\left\{\left(\frac{t-t_c}{F(y_c)}\right)^{1-\alpha} s_0 E_0[y] - \left(\frac{t_c}{1-F(y_c)}\right)^{1-\alpha} s_x E_x[y]\right\}}_{B}$$

$$+ \underbrace{(1-\alpha)\frac{dt_c}{dy_c}\left\{-\left(\frac{t-t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] + \left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha} s_x E_0[y]\right\}}_{C} \quad (17)$$

The total effect of a change in the cut-off level y_c on the level of expected costs borne by potential victims consists of three different effects. Term A indicates that an increase in y_c implies that this property value is no longer protected. At the value of $\tilde{y}_c$ that results in the decentralized equilibrium, this effect is equal to zero due to (15). Second, the change in y_c varies the number of protected and unprotected potential victims and thereby the victimization probabilities for respective groups, which is mirrored by term B. Third, varying y_c makes a reallocation of thieves optimal (term C). This happens according to optimality considerations of offenders (see (14)) so that this effect is equal to zero at the decentralized equilibrium. In summary, in order to establish whether or not the socially optimal solution for the cut-off y_c is greater than the privately optimal level, we need to consider term B more closely.

Using (14) to substitute $(t-t_c)F(y_c)^{-1}t_c^{-\alpha}(1-F(y_c))^{\alpha}s_x E_x[y]$ for $(t-t_c)^{1-\alpha}F(y_c)^{\alpha-1}s_0 E_0[y]$, we can state that the sign of term B will be positive when

$$s_x E_x[y]\left(\frac{t_c}{1-F(\tilde{y}_c)}\right)^{-\alpha}\left[\frac{t-t_c}{F(\tilde{y}_c)} - \frac{t_c}{1-F(\tilde{y}_c)}\right] < 0 \quad (18)$$

due to $\alpha \in (0,1)$. When inequality (18) is valid, this implies that $dW_A/dy_c > 0$ at $\tilde{y}_c$. Given that W_A represents expected costs for the collective of victims, the positive value of the derivative means that victims would be better off when they stop at a lower level of y_c (i.e., that the privately optimal investment in protection against crime is suboptimal). Note that

$$\frac{t-t_c}{F(\tilde{y}_c)} < \frac{t_c}{1-F(\tilde{y}_c)} \quad (19)$$

$$\Leftrightarrow q(t-t_c, F(\tilde{y}_c)) = \left(\frac{t-t_c}{F(\tilde{y}_c)}\right)^{-\alpha} > \left(\frac{t_c}{1-F(\tilde{y}_c)}\right)^{-\alpha} = q(t_c, 1-F(\tilde{y}_c)) \quad (20)$$

$$\Leftrightarrow s_0 E_0[y] < s_x E_x[y] \quad (21)$$

In words, when the ratio of thieves to potential victims is indeed greater for the group of protected targets (19), then thieves' probability to find a suitable target is smaller when they focus on protected households (20). This in turn requires that the expected appropriable share of property must be greater for protected than for unprotected victims ((21) due to (14)).

This allows to derive the following result:

Proposition 2 *Suppose that the number of criminals is given and that information about property value is private. Then, decentralized investments in precaution against crime are suboptimal (excessive) when compared to the social optimum when*

$$s_0 E_0[y] < (>)\, s_x E_x[y]$$

Proof. Starting at $y_c = \tilde{y}_c$, Term A and C in (17) are equal to zero. Term B is positive (negative) when (18) is (not) fulfilled, indicating that it is optimal to decrease (increase) y_c. ■

When potential victims determine whether or not to invest in private protection measures without consulting fellow potential victims, they select to invest to an extent that may fall short of the extent that proves optimal for all potential victims taken together. Private protection makes it harder for criminals to succeed at a given target on the one hand, but indicates that the given target is particularly worthwhile on the other. Given the two opposing effects, the diversion and the attraction effects, it depends on their relative importance. Accordingly, for underinvestment to arise, it is required that $s_0 E_0[y] < s_x E_x[y]$ at $\tilde{y}_c$. This implies that the impact the observation of private precaution by thieves has on the ratio of expected property values E_x/E_0 exceeds the impact on the shares of the property that is appropriable s_0/s_x. In other words, all else held equal, thieves are more interested in a given target that is protected because of the higher expected property value, even if this implies that it is more difficult to appropriate property. In this sense, private protection makes a given potential victim a target that is more worthwhile (i.e., it *attracts* thieves). This can explain that too few victims make the investment in precautions. When (18) is not fulfilled, the attraction effect is dominated by the diversion effect such that privately optimal safety expenditures are excessive when evaluated from the point of view of all victims taken together.

Decentralized investment decisions yield suboptimal precaution levels when the probability for a thief to find a suitable target is higher among unprotected potential victims (see (20)). This probability is a construct that is difficult to approximate from available data. The empirical evidence regarding estimates of the victimization probability suggests that victimization is less likely for well-to-do households than for less well-off ones, as we explained in our introduction. When we interpret s_p as a probability, this would imply in terms of our framework that it holds empirically that

$$\left(\frac{t-t_c}{F(\tilde{y}_c)}\right)^{1-\alpha} s_0 > \left(\frac{t_c}{1-F(\tilde{y}_c)}\right)^{1-\alpha} s_x. \tag{22}$$

Stating this as

$$\frac{s_0}{s_x} > \left(\frac{t_c/(1-F(\tilde{y}_c))}{(t-t_c)/F(\tilde{y}_c)}\right)^{1-\alpha}, \tag{23}$$

we see that the condition (19) that is required for the finding of suboptimal private investment in precaution against crime (i.e., that the right-hand side is greater than one) may very well be compatible with the empirical regularity, since $s_0/s_x > 1$.

5 Extension: Endogenous crime participation

Before we conclude our study, we briefly consider the possibility that the number of thieves t is endogenously determined for our main scenario in which the property value is private information. Suppose that potential thieves face a lawful alternative that pays w and that potential thieves differ in their productivity in lawful occupations so that $w \in [\underline{w}, \bar{w}]$ according to $G(w)$. The potential thief who is as well off with legal work as with theft earns

$$\hat{w} = \left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha} s_x E_x[y] \tag{24}$$

which gives an additional equilibrium condition when defining the behavior of potential thieves. From this, the measure of thieves is given by $t = G(\hat{w})$. Accordingly, to describe the equilibrium with regard to decision-making by potential thieves, we need to take into account that only potential thieves with $w \leq \hat{w}$ participate in the criminal sector (participation condition (24)) and that offenders must be indifferent between different target groups (condition determining the allocation of thieves (14)).

Potential victims individually decide on private precautions against crime according to (15) irrespective of whether the crime rate is endogenous or not. In contrast, in the case of centralized decision-making, victims internalize that a variation in the cut-off y_c bears additional repercussions due to the endogenous crime participation decision. The minimand accordingly uses the share of thieves $G(\hat{w})$ instead of the fixed number t used before. This leads to

$$\min_{y_c} W_E = \left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{1-\alpha} s_0 \int_0^{y_c} y dF(y) + \left(\frac{t_c}{1-F(y_c)}\right)^{1-\alpha} s_x \int_{y_c}^1 y dF(y) + x[1-F(y_c)] \quad (25)$$

The collectively optimal level of y_c when the number of thieves is endogenous fulfills

$$\begin{aligned}\frac{dW_E}{dy_c} = & \underbrace{f(y_c)\left[\left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{1-\alpha} s_0 y_c - \left\{\left(\frac{t_c}{1-F(y_c)}\right)^{1-\alpha} s_x y_c + x\right\}\right]}_{A} \\ & + \underbrace{f(y_c)(\alpha-1)\left\{\left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{1-\alpha} s_0 E_0[y] - \left(\frac{t_c}{1-F(y_c)}\right)^{1-\alpha} s_x E_x[y]\right\}}_{B} \\ & + \underbrace{(1-\alpha)\frac{dt_c}{dy_c}\left\{-\left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] + \left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha} s_x E_0[y]\right\}}_{C} \\ & + \underbrace{(1-\alpha)g(\hat{w})\frac{d\hat{w}}{dy_c}\left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y]}_{D} \end{aligned} \quad (26)$$

The additional marginal effect is represented by term D, which sign is determined by $d\hat{w}/dy_c$. When a decrease in the share of protected victims (i.e., an increase in y_c) makes it more attractive to become a thief (i.e., when $\hat{w}$ increases), then this additional marginal effect is positive and intuitively argues for a lower level of the cut-off y_c. In that case, we obtain the result established before (e.g., Shavell 1991) that decentralized decision-making regarding security expenditures may be suboptimal because the consequences for the payoff from crime are not internalized by potential victims when they decide on their own. In the appendix, we establish that $d\hat{w}/dy_c > 0$ necessarily results when $(G(\hat{w}) - t_c)/F(y_c) > t_c/(1 - F(y_c))$ (i.e., when the relative share of thieves is higher for non-protected households). In that case, starting at the share of protected victims that results under decentralized decision-making, term B points at excessive precaution investments (to see this, refer to (18)) while term D indicates that the influence on the crime rate may make privately optimal investment insufficient from the collective standpoint, leaving the total effect unsettled (as in, e.g., Shavell 1991). Alternatively, when $(G(\hat{w}) - t_c)/F(y_c) < t_c/(1-F(y_c))$, we may obtain the outcome that there is too little investment due to the attraction effect on the one hand but too much investment on the other hand, where the latter conclusion may follow when less investment counterintuitively lowers crime (i.e., when $d\hat{w}/dy_c < 0$).

6 Conclusion

Private precautions against crime play an integral role in crime control. For the case in which private security expenditures do not affect the crime rate but only the allocation of criminals on potential victims, the literature has argued that decentralized decision-making will result in socially excessive investment due to the diversion effect of private action against crime. Potential victims will invest in protection even when that implies that potential offenders are only send next door. This finding has been derived for the at times unrealistic assumption of perfectly observable property values. Our analysis replicates this finding for the perfect information scenario and, more importantly, establishes that potential victims may invest suboptimally when private precaution expenditures inform thieves about the value of the property to be protected.

Our result implies for policy makers that, contrary to received wisdom, subsidies may be required in order to arrive at socially optimal levels of investment in private protection against crime. At least, the identified effect dampens the discrepancy between the private net benefit from investment and the social one, and thus cautions regarding the taxation of private protection goods.

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Appendix

In the centralized asymmetric information setting, victims choose y_c in anticipation of how criminals will respond. The behavior by criminals is described by

$$A := \left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] - \left(\frac{t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y] = 0 \tag{27}$$

$$B := \hat{w} - \left(\frac{t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y] = 0 \tag{28}$$

where $\hat{w} \in [\underline{w}, \bar{w}]$ is the critical wage so that $G(\hat{w})$ is the number of potential offenders.

$$\begin{pmatrix} A_{\hat{w}} & A_{t_c} \\ B_{\hat{w}} & B_{t_c} \end{pmatrix} \begin{pmatrix} d\hat{w} \\ dt_c \end{pmatrix} = \begin{pmatrix} -A_{y_c} \\ -B_{y_c} \end{pmatrix} dy_c \tag{29}$$

where D,

$$D = A_{\hat{w}} B_{t_c} - B_{\hat{w}} A_{t_c} \tag{30}$$

denotes the determinant of the 2×2 matrix on the left-hand side in our subsequent argumentation.

We obtain

$$A_{\hat{w}} = -\alpha (G(\hat{w}) - t_c)^{-1} \left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{-\alpha} g(\hat{w}) s_0 E_0[y] < 0 \tag{31}$$

$$A_{t_c} = \alpha (G(\hat{w}) - t_c)^{-1} \left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] + \alpha t_c^{-1} \left(\frac{t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y] > 0 \tag{32}$$

$$\begin{aligned} A_{y_c} &= s_0 \left(\frac{G(\hat{w}) - t_c}{F(y_c)}\right)^{-\alpha} \left\{\frac{dE_0[y]}{dy_c} + \alpha E_0[y] \frac{f(y_c)}{F(y_c)}\right\} \\ &\quad + s_x \left(\frac{t_c}{1 - F(y_c)}\right)^{-\alpha} \left\{\alpha E_x[y] \frac{f(y_c)}{1 - F(y_c)} - \frac{dE_x[y]}{dy_c}\right\} \end{aligned} \tag{33}$$

$$B_{\hat{w}} = 1 > 0 \tag{34}$$

$$B_{t_c} = \alpha s_x E_x[y] t_c^{-1} \left(\frac{t_c}{1 - F(y_c)}\right)^{-\alpha} > 0 \tag{35}$$

$$B_{y_c} = s_x \left(\frac{t_c}{1 - F(y_c)}\right)^{-\alpha} \left\{-\frac{dE_x[y]}{dy_c} + \alpha E_x[y] \frac{f(y_c)}{1 - F(y_c)}\right\} \tag{36}$$

so that all terms except for A_{y_c} and B_{y_c} can be unambiguously signed and imply $D < 0$.

Note that

$$\frac{dE_0[y]}{dy_c} = f(y_c)\frac{y_c - E_0[y]}{F(y_c)} > 0 \tag{37}$$

$$\frac{dE_x[y]}{dy_c} = f(y_c)\frac{E_x[y] - y_c}{1 - F(y_c)} > 0 \tag{38}$$

We are interested in the way in which $\hat{w}$ responds to an increase in the cut-off property value y_c. For this question, we need to determine the sign of

$$-D\frac{d\hat{w}}{dy_c} = A_{y_c}B_{t_c} - B_{y_c}A_{t_c} \tag{39}$$

where

$$\begin{aligned} A_{y_c}B_{t_c} =& \alpha s_x E_x[y] t_c^{-1} f(y_c)\left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha} \\ & \times \left[s_x\left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha}\frac{y_c - (1-\alpha)E_x[y]}{1-F(y_c)} + s_0\left(\frac{G(\hat{w})-t_c}{F(y_c)}\right)^{-\alpha}\frac{y_c-(1-\alpha)E_0[y]}{F(y_c)}\right] \end{aligned} \tag{40}$$

and

$$\begin{aligned} B_{y_c}A_{t_c} =& \alpha s_x\left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha} f(y_c)\frac{y_c-(1-\alpha)E_x[y]}{1-F(y_c)} \\ & \times \left[s_x t_c^{-1}E_x[y]\left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha} + s_0(G(\hat{w})-t_c)^{-1}E_0[y]\left(\frac{G(\hat{w})-t_c}{F(y_c)}\right)^{-\alpha}\right] \end{aligned} \tag{41}$$

Returning to (39), we obtain

$$\begin{aligned} D\frac{d\hat{w}}{dy_c} =& \alpha s_0 s_x f(y_c)\left(\frac{t_c}{1-F(y_c)}\right)^{-\alpha}\left(\frac{G(\hat{w})-t_c}{F(y_c)}\right)^{-\alpha} \\ & \times \left[\frac{y_x E_x[y] - E_0[y]E_x[y](1-\alpha)}{F(y_c)t_c} - \frac{y_x E_0[y] - E_0[y]E_x[y](1-\alpha)}{(1-F(y_c))(G(\hat{w}-t_c)}\right] \end{aligned} \tag{42}$$

Accordingly, the condition $(G(\hat{w}) - t_c)/F(y_c) > t_c/(1 - F(y_c))$ is a sufficient condition since the term in brackets is positive as long as

$$\frac{G(\hat{w})-t_c)/F(y_c)}{t_c/(1-F(y_c))} > \frac{y_x E_0[y] - E_0[y]E_x[y](1-\alpha)}{y_x E_x[y] - E_0[y]E_x[y](1-\alpha)} \tag{43}$$

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Heinrich-Heine-University of Düsseldorf

Düsseldorf Institute for
Competition Economics (DICE)

Universitätsstraße 1 _ 40225 Düsseldorf
www.dice.hhu.de

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