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Private Protection against Crime when Property Value is Private Information

Abstract

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

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1 Introduction

1.1 Motivation and main results

Crime is a social phenomenon of great importance that adversely affects scores of people every minute of every day. Indeed, crime is consistently placed at or near the top of ranked lists of social maladies (see, e.g., Helsley and Strange 1999). Potential victims go to considerable lengths in private attempts to lower the risk of crime. These private precautions include not only minor expenses (such as making a detour while walking to avoid a dark alley) but also sizable investments (such as security systems to safeguard one's private home); it has been empirically estimated that private precaution expenditures are at least of the same order of magnitude as public anti-crime expenditures (Shavell 1991). Despite its significance in crime control efforts, private protection has received little scholarly attention in comparison 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 can deter crime and/or *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 against crime without taking into account the adverse consequences for those whose crime risk increases as a result of the investment; the outcome is an *overinvestment* in private precautions 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,

[1]The literature on private action against crime distinguishes between measures of observable protection, 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.

concluding that crime 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 rather than 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 the one hand, private protection makes it more difficult for criminals to successfully burgle a given target; on the other hand, private protection indicates that the given target is particularly worthwhile. For example, a surveillance camera in front of a private house makes successful burglary more difficult, but it also indicates that valuable goods are being protected by the homeowners. Taking into account these two opposing effects, diversion and attraction, 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 therefore underinvestment is privately optimal).

Our central result is derived in a setting in which potential victims differ in the level of property value at risk of crime. The number of suitable targets a thief expects to find is determined by a function that takes into account both the number of thieves focusing on the same subgroup of potential victims and the number of potential victims in that subgroup (in order to reflect congestion of criminal opportunities). 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 previous findings of overinvestment in private precautions for a given level of crime by comparing the individually optimal investment in private anti-crime precautions to the optimal level for the entire group of potential victims.[2] Next, we consider the fact that property values are generally not easily observable. We assume that potential victims have private information about the value of their property, and may signal some information about this value by deciding 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, a thief will revise his or her estimation of the expected value of a property upon observing (no) private protection and will

[2] The level of precautions that victims would collectively agree upon is also considered as a benchmark in Shavell (1991, see also fn. 9). The objective function we consider when we examine the optimal private precautions against crime from a social standpoint is the sum of the expected stolen goods and the protection expenditures; this may be referred to as the aggregate burden of crime (as in, e.g., Hotte and van Ypersele 2008).

attempt to steal where expected profits are the highest. 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 arising from the diversion effect, implying that private decisions will not be as disparate from that of the social planner as has been previously proposed.

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 from the National Crime Victimization Survey, households with an annual income between $15,000 and $25,000 suffered 32.8 burglary victimizations per thousand households, whereas those with income $75,000 and higher experienced only 16.7 victimizations (Bureau of Justice Statistics 2011). The outcome of our model thus corresponds to real-life situations.

1.2 Relation to the literature

The present study analyzes potential victims' private protection investment when property values vary and are private information, examining whether the resulting levels of investment are aligned with socially optimal levels. The empirical importance for this setting is forcefully advocated by Mikos (2006), for example.

For simplicity, we disregard public law enforcement (as in, e.g., Shavell 1991). The interplay between private precautions and public enforcement was an early subject of interest (Clotfelter 1977) and continues to be so (see, e.g., Grechenig and Kolmar 2011, Helsley and Strange 2005). In this field, Hylton (1996) has established that potential victims may invest too little in private action, as they externalize part of the increase in social costs through an increase in the enforcement costs of the state.

The reasons for differences between private and social incentives with respect to investments in private protection against crime include the diversion effect described above. In a setting in which potential differences between victims are public information, Hui-Wen and Png (1994) establish that private security expenditures are more likely to divert crime when potential thieves can more easily switch between victims. In our framework, offenders can switch at no cost, which tilts our model towards the overinvestment result for a given level of crime. Another discrepancy between the private and the social optimum stems from the fact that private protection against crime lowers the expected payoff from crime in equilibrium and thereby confers a benefit to all potential victims (see, e.g., Shavell 1991). By public-goods reasoning, decentralized decision-making is likely to induce underinvestment 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 includes criminals' benefits from crime as social benefits. In such a scenario, it may be the case 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 the social benefits of crime.[3]

The contribution of the present paper lies in establishing that the informative value of private protection for potential offenders is a possible cause for private investment falling below 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 property values are 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 does not allow consideration of the empirically relevant diversion effect. In our paper, in contrast, offenders can freely choose between potential targets, enabling us to analyze the relationship between the diversion effect and the attraction effect. In addition, 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

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

which there is asymmetric information regarding the property value. Section 5 considers the idea that decisions regarding private protection could influence the number of individuals who opt to commit crime. Section 6 concludes the study.

2 The model

We consider two types of individuals: potential criminals and potential victims of crime. With regard to the latter, we assume that there is a continuum of risk-neutral potential victims normalized to one. Potential victims own property value of 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. Precaution (no precaution) is associated with costs $p = x > 0$ ($p = 0$).[4] The expected property that a thief can steal is given by $s_p y$, $s_p \in (0,1)$, where the assumption $\Delta s = s_0 - s_x > 0$ reflects the effectiveness of private protection. In our model, the term s_p may be interpreted as the proportion of the property acquired (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).

There is a number t of identical risk-neutral thieves who can direct their search for a target to a type θ. Except in Section 5, t will be considered an exogenous parameter.[5] 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., $\theta \in [0,1] \times \{0,x\}$); in the case of asymmetric information, in contrast, there are only protected and unprotected targets (i.e., $\theta \in \{0,x\}$). In order to arrive at the expected payoff from attempted theft with a target of type θ, the expected value of the stolen property must be weighted by the number of suitable targets the thief expects to find; this is denoted by q, a function of the number of thieves focusing on the same type of target, T_θ, and the number of potential victims of the given type, V_θ. In this way, we reflect the congestion of

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

[5] We are interested in the relationship between the diversion and the attraction effect. These aspects come to the fore most clearly when the level of crime is fixed. Note that the divergence between 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).

criminal opportunities (as has been assumed by Helsley and Strange 2005, among others) in accordance with the concept of the matching function used extensively in labor economics (see, e.g., Petrongolo and Pissarides 2001). The expected number of identified targets consequently increases with the number of households of a given type and decreases with the number of thieves having the same focus, $\partial q/\partial T < 0 < \partial q/\partial V$; in the following analysis, this will be approximated by $q_\theta = (T_\theta/V_\theta)^{-\alpha}$, with $\alpha \in (0,1)$. As a result, q increases at a decreasing rate with the number of potential victims of a given type, because the existence of more victims naturally decreases the congestion of criminal opportunities. At the same time, q decreases at a diminishing rate with the number of thieves when the number of potential victims is held constant. We assume that the number of thieves t is small enough to ensure that $T_\theta/V_\theta < 1$ for all θ.[6] 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 are realized.

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 subsequent section analyzing asymmetric information on the value of property. First, we derive the equilibrium under decentralized decision-making. We then consider what is collectively optimal for potential victims given how thieves decide on worthwhile targets, which allows us to identify potential deviations between the private and the collective choice.

3.1 Decentralized decision-making

At Stage 2, after potential victims have made their Stage 1 decisions on private protection, thieves can perfectly discriminate between different target types; a target is identified by the

[6] This implies that thieves expect to steal from more than one household. It is important to note the following: To arrive at q, we use m/t as a matching function, with $m = V^\alpha T^{1-\alpha}$. If we were instead to use $m' = fm$ with $f < 1$, this would allow us to interpret q as a probability. In the interest of simplicity, we do not introduce f.

property value at risk and the private precaution expenditures invested. 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 were higher, causing this expected payoff to fall and other payoffs to increase (via the congestion effect inherent in the function q). With respect to the private precaution measures determined at Stage 1, it results that there is a critical level for the property value, such that private protection expenditures will be invested for property values above this threshold and not for property values below this critical value. Denoting the property value at which potential victims are indifferent regarding investing or not investing in private protection with y_c, we find that

$$t(y)^{-\alpha} s_0 y = k \ \forall y < y_c \tag{1}$$

$$t(y)^{-\alpha} s_x y = k \ \forall y \geq y_c, \tag{2}$$

where $t(y)$ is the number of thieves focusing on property value y and k indicates the expected benefits for a thief (equalized across target types). The number of thieves then follows as

$$t(y) = \left(\frac{s_0 y}{k}\right)^{1/\alpha} \quad \forall y < y_c \tag{3}$$

$$t(y) = \left(\frac{s_x y}{k}\right)^{1/\alpha} \quad \forall y \geq y_c. \tag{4}$$

Consequently, the number of thieves who focus on target y 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 $y = y_c$ which compensates for the differential Δs, such that $t(y_c - \epsilon)|_{p=0} > t(y_c)|_{p=x}$ with $\epsilon \to 0$.

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 add up to the total number of thieves:

$$t = \int_0^{y_c} \left(\frac{s_0 y}{k}\right)^{1/\alpha} dF(y) + \int_{y_c}^1 \left(\frac{s_x y}{k}\right)^{1/\alpha} dF(y). \tag{5}$$

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

$$\frac{dk}{dy_c} = \alpha \frac{k^{(\alpha-1)/\alpha} y_c^{1/\alpha} f(y_c)[s_0^{1/\alpha} - s_x^{1/\alpha}]}{t} > 0. \tag{6}$$

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.

Turning to the decision of potential victims over whether or not to invest in private protection against crime at Stage 1, we find that the potential victim who is indifferent between the two options will have a property value described by

$$\left(t(y_c)|_{p=0}\right)^{1-\alpha}\ s_0 y_c = \left(t(y_c)|_{p=x}\right)^{1-\alpha}\ s_x y_c + x. \tag{7}$$

The individual victimization probability results from the combination of the number of suitable targets a thief expects to find with the probability that a given household of the specific type will be affected. We therefore assume that the number of thieves with a focus on targets with income y and a given level of protection are equally distributed across targets with income y (similar to Shavell 1991). The cut-off property value is such that the owner can invest in private protection in exchange for a decrease in the appropriable property without being better or worse off than without private action. Rearranging (7) using (3) and (4) leads to

$$y_c^* = \left(\frac{x}{s_0^{1/\alpha} - s_x^{1/\alpha}}\right)^{\alpha} k^{1-\alpha}. \tag{8}$$

Intuitively, fewer property owners will invest in private protection (i.e., y_c will be higher) when it is more expensive or less effective (as measured by a lower Δs). Private protection is rated less worthy of investment as k increases, which by (5) is equivalent to a lower number of thieves t and consequently a lower rate of victimization.

The equilibrium is established by simultaneously solving for the values of k and y_c^* from (5) and (8).

3.2 Centralized decision-making

We now assume that potential victims will seek to collectively minimize the losses that the risk of crime imposes on the entire group of potential victims by choosing the cut-off level y_c that separates protected property holders from the unprotected. This will be considered the socially optimal choice. In so doing, potential victims anticipate how thieves determine which target to focus on. The minimand is expected costs, which consists of the expected stolen property value and the precaution expenditures (as in, e.g., Hotte and van Ypersele 2008).

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

The collectively optimal level of y_c fulfills

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

The total effect of a change in the proportion of protected potential victims on the level of expected costs borne by all potential victims includes both 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 (6), which influences how thieves are distributed across potential victims, as described in (3)-(4).

This allows us to derive the following result:

Proposition 1 *Suppose that the number of criminals is given and that information about property values and private precaution is freely available. Then, decentralized investments in precaution against crime 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 value 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 overinvest. This is a consequence of potential victims not internalizing the fact that a reduction in their expected loss of property achieved by private ant-crime action implies that other property holders will be exposed to crime to a greater extent. With this finding, our setup replicates the diversion effect that has been previously established in the literature.

4 Asymmetric information

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

4.1 Decentralized decision-making

When the value of property is private information, potential thieves at Stage 2 can only distinguish between targets that are protected and those that are unprotected. For each group of targets, the expected property value is contingent on the observation of (no) private precautions. The expected property value of protected targets is given by $E_x[y] = (1 - F(y_c))^{-1} \int_{y_c}^{1} y dF(y)$, and the expected property value of unprotected targets is given by $E_0[y] = F(y_c)^{-1} \int_0^{y_c} y dF(y)$. Therefore, potential thieves understand that investing in private protection against crime is beneficial only for owners of property with a reasonably high value. In other words, private protection signals that the property value is relatively high.

In equilibrium, it must hold that

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

where t_c $(t - t_c)$ represents the number of potential thieves who focus on unprotected (protected) targets. When (11) holds, potential thieves are indifferent with regard to the type of target.

Next, we turn to Stage 1, in which the investment in private protection against crime is determined by each potential victim. The potential victim who is just indifferent over whether or not to purchase private protection owns property whose value fulfills

$$\left(\frac{t_c}{F(\tilde{y}_c)}\right)^{1-\alpha} s_0 \tilde{y}_c = \left(\frac{t - t_c}{1 - F(\tilde{y}_c)}\right)^{1-\alpha} s_x \tilde{y}_c + x. \tag{12}$$

The first term on the right-hand (left-hand) side of the equation represents the probability that a given (un-)protected potential victim will in fact be victimized. In contrast to the benchmark case with observable property values, this probability is the same for all different property values in the group of protected properties and for those in the group of unprotected properties. With public information on property values, this probability was also conditional on the value of the property. Equations (11) and (12) establish the equilibrium values for t_c and $\tilde{y}_c$.

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, which determines the ratio between protected and unprotected property holders. The objective function of potential victims must take into account the fact that thieves act only on the signal obtained from private protection, rather than on the combination of precaution and property value. This is represented by

$$W_A = \left(\frac{t_c}{F(y_c)}\right)^{1-\alpha} s_0 \int_0^{y_c} ydF(y) + \left(\frac{t-t_c}{1-F(y_c)}\right)^{1-\alpha} s_x \int_{y_c}^{1} ydF(y) + x[1-F(y_c)]. \tag{13}$$

The collectively optimal level of y_c fulfills

$$\begin{aligned}\frac{dW_A}{dy_c} =& \underbrace{f(y_c)\left(\frac{t_c}{F(y_c)}\right)^{1-\alpha} s_0 y_c - f(y_c)\left\{\left(\frac{t-t_c}{1-F(y_c)}\right)^{1-\alpha} s_x y_c + x\right\}}_{A} \\ & \underbrace{+ f(y_c)(\alpha-1)\left\{\left(\frac{t_c}{F(y_c)}\right)^{1-\alpha} s_0 E_0[y] - \left(\frac{t-t_c}{1-F(y_c)}\right)^{1-\alpha} s_x E_x[y]\right\}}_{B} \\ & \underbrace{+ (1-\alpha)\frac{dt_c}{dy_c}\left\{\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] - \left(\frac{t-t_c}{1-F(y_c)}\right)^{-\alpha} s_x E_x[y]\right\}}_{C}. \end{aligned} \tag{14}$$

The total effect of a change in the cut-off level y_c on the level of expected costs borne by potential victims is composed of three different effects. Term A indicates that an increase in y_c will imply 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 (as a result of (12)). Second, change in y_c varies the number of protected and unprotected potential victims and thereby the victimization probabilities for the respective groups, which is reflected in term B. Third, varying y_c makes a reallocation of thieves optimal (term C). This takes place according to the optimality considerations of offenders (see (11)), such 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 must examine term B in greater detail.

Using (11) to substitute $t_c F(y_c)^{-1}(t-t_c)^{-\alpha}(1-F(y_c))^{\alpha} s_x E_x[y]$ for $t_c^{1-\alpha} F(y_c)^{\alpha-1} s_0 E_0[y]$, we can state that the sign of term B will be positive when

$$s_x E_x[y] \left(\frac{t-t_c}{1-F(\tilde{y}_c)}\right)^{-\alpha} \left[\frac{t_c}{F(\tilde{y}_c)} - \frac{t-t_c}{1-F(\tilde{y}_c)}\right] < 0 \tag{15}$$

since $\alpha \in (0,1)$. When inequality (15) is valid, this implies that $dW_A/dy_c > 0$ at $\tilde{y}_c$. Given that W_A represents expected costs for the collective group of victims, the positive value of the derivative means that victims would be better off if they fixed a lower level for y_c (i.e., that the privately optimal investment in protection against crime is suboptimal). Note that

$$\frac{t_c}{F(\tilde{y}_c)} < \frac{t - t_c}{1 - F(\tilde{y}_c)} \tag{16}$$

$$\Leftrightarrow q(t_c, F(\tilde{y}_c)) = \left(\frac{t_c}{F(\tilde{y}_c)}\right)^{-\alpha} > \left(\frac{t - t_c}{1 - F(\tilde{y}_c)}\right)^{-\alpha} = q(t - t_c, 1 - F(\tilde{y}_c)) \tag{17}$$

$$\Leftrightarrow s_0 E_0[y] < s_x E_x[y] \tag{18}$$

In other words, when the ratio of thieves to potential victims is indeed greater for the group of protected targets (see (16)), then the number of suitable targets the thief expects to find is smaller when they focus on protected households (see (17)). This in turn requires that the expected value of the stolen property must be greater for protected than for unprotected victims (see (18) resulting from (11)).

This allows us 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) in comparison 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 (14) are equal to zero. Term B is positive (negative) when (15) 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 choose to invest to an extent that may fall short of the optimal extent for all potential victims as a whole. Private protection makes it more difficult for criminals to succeed at burgling a given target, but it also indicates that the target is particularly worthwhile. Given these two opposing effects (diversion and attraction), the overall effect depends on their relative importance. Accordingly, for underinvestment to occur, it is necessary 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 dominates the impact on the ratio of property shares not secured against theft s_0/s_x. In other words, all else held equal, thieves are more interested in a target that is protected because of its higher expected property value, even though this implies that the property will be more difficult to steal. In this sense, private protection makes a potential victim a more tempting target (i.e., it *attracts* thieves). This can explain why too few victims make investments in precautions. When (15) 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 the victims as a collective.

Decentralized investment decisions yield suboptimal precaution levels when the number of suitable targets thieves expect to find is higher among unprotected potential victims (see (17)). This number is a construct that is difficult to approximate from the available data. The empirical evidence regarding estimates of the victimization probability suggests that victimization is less likely for well-to-do households than for the less well-off, as we explained in our introduction. If we interpret s_p as a probability, this would imply in terms of our framework that it holds empirically that

$$\left(\frac{t_c}{F(\tilde{y}_c)}\right)^{1-\alpha} s_0 > \left(\frac{t-t_c}{1-F(\tilde{y}_c)}\right)^{1-\alpha} s_x. \tag{19}$$

Restating this as

$$\frac{s_0}{s_x} > \left(\frac{(t-t_c)/(1-F(\tilde{y}_c))}{t_c/F(\tilde{y}_c)}\right)^{1-\alpha}, \tag{20}$$

we see that the condition (16) required for suboptimal private investment in precaution against crime (i.e., that the right-hand side be 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 are faced with a lawful alternative that pays w, and that these potential lawbreakers differ in their productivity in lawful occupations, such that $w \in [\underline{w}, \bar{w}]$ according to $G(w)$. The potential thief who would benefit equally from legal work and from theft earns

$$\hat{w} = \left(\frac{t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y], \tag{21}$$

which provides an additional equilibrium condition for defining the behavior of potential thieves. It follows that the number of thieves is given by $t = G(\hat{w})$. Consequently, in order to describe the equilibrium with regard to decision-making by potential thieves, we must take into account the facts that only potential thieves with $w \leq \hat{w}$ will participate in criminal activities (participation condition (21)) and that offenders must be indifferent regarding the various target groups (condition determining the allocation of thieves (11)).

Potential victims individually decide on private precautions against crime according to (12), irrespective of whether the crime rate is endogenous or not. In contrast, in the case of centralized decision-making, victims internalize the fact that a variation in the cut-off value y_c will incur additional repercussions due to the endogenous crime participation decision. The minimand therefore makes use of the number of thieves $G(\hat{w})$ instead of the fixed number t previously incorporated. This leads to

$$\min_{y_c} W_E = \left(\frac{t_c}{F(y_c)}\right)^{1-\alpha} s_0 \int_0^{y_c} y dF(y) + \left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{1-\alpha} s_x \int_{y_c}^{1} y dF(y) + x[1 - F(y_c)]. \quad (22)$$

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

$$\begin{aligned}\frac{dW_E}{dy_c} &= \underbrace{f(y_c)\left[\left(\frac{t_c}{F(y_c)}\right)^{1-\alpha} s_0 y_c - \left\{\left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{1-\alpha} s_x y_c + x\right\}\right]}_{A} \\ &\quad + \underbrace{f(y_c)(\alpha - 1)\left\{\left(\frac{t_c}{F(y_c)}\right)^{1-\alpha} s_0 E_0[y] - \left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{1-\alpha} s_x E_x[y]\right\}}_{B} \\ &\quad + \underbrace{(1-\alpha)\frac{dt_c}{dy_c}\left\{\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] - \left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y]\right\}}_{C} \\ &\quad + \underbrace{(1-\alpha)g(\hat{w})\frac{d\hat{w}}{dy_c}\left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y]}_{D}. \end{aligned} \quad (23)$$

The additional marginal effect is represented by term D, the sign of which is determined by $d\hat{w}/dy_c$. When a decrease in 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 value y_c. In this case, we obtain the previously established result (e.g., Shavell 1991) that decentralized decision-making regarding security expenditures may be suboptimal: The consequences for the payoffs from crime are not internalized by potential victims when they decide in isolation. In the appendix, we establish that $d\hat{w}/dy_c > 0$ necessarily results when $t_c/F(y_c) > (G(\hat{w}) - t_c)/(1 - F(y_c))$ (i.e., when the relative number of thieves is higher for non-protected households). In this case, starting at the proportion of protected victims that results under decentralized decision-making, term B points to excessive investment in precaution (see (15)); however, term D indicates that the influence on the crime rate may make privately optimal investment insufficient from the collective standpoint, leaving the total effect unclear (as in, e.g., Shavell 1991). Alternatively, when $t_c/F(y_c) < (G(\hat{w}) - t_c)/(1 - F(y_c))$, we may obtain the outcome that on the one hand there is too little investment due to the attraction effect, but too much investment when less investment counterintuitively lowers crime (i.e., when $d\hat{w}/dy_c < 0$) on the other, leaving the total effect unclear.

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 to potential victims, the literature has argued that decentralized decision-making will result in an investment level that is socially excessive as a result of the diversion effect. Potential victims will invest in protection even when this implies that offenders will simply be sent 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 transmit information to thieves about the value of the protected property.

For policy makers, our result implies 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 the least, the effect identified in our analysis moderates the discrepancy between the private net benefit from investment in protection and the social benefit, and thus indicates that caution is required 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 of criminals is described by

$$A := \left(\frac{t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] - \left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y] = 0 \tag{24}$$

$$B := \hat{w} - \left(\frac{t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] = 0 \tag{25}$$

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

$$\begin{pmatrix} A_{\hat{w}} & A_{t_c} \\ B_{\hat{w}} & B_{t_c} \end{pmatrix} \begin{pmatrix} d\hat{w} \\ dt_c \end{pmatrix} = \begin{pmatrix} -A_{y_c} \\ -B_{y_c} \end{pmatrix} dy_c, \tag{26}$$

where D,

$$D = A_{\hat{w}} B_{t_c} - B_{\hat{w}} A_{t_c}, \tag{27}$$

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

We obtain

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

$$A_{t_c} = -\alpha t_c^{-1}\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} s_0 E_0[y] - \alpha(G(\hat{w}) - t_c)^{-1}\left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha} s_x E_x[y] < 0 \tag{29}$$

$$\begin{aligned} A_{y_c} &= s_0\left(\frac{t_c}{F(y_c)}\right)^{-\alpha}\left\{\frac{dE_0[y]}{dy_c} + \alpha E_0[y]\frac{f(y_c)}{F(y_c)}\right\} \\ &+ s_x\left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha}\left\{\alpha E_x[y]\frac{f(y_c)}{1 - F(y_c)} - \frac{dE_x[y]}{dy_c}\right\} \end{aligned} \tag{30}$$

$$B_{\hat{w}} = 1 > 0 \tag{31}$$

$$B_{t_c} = \alpha s_0 E_0[y] t_c^{-1}\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} > 0 \tag{32}$$

$$B_{y_c} = s_0\left(\frac{t_c}{F(y_c)}\right)^{-\alpha}\left\{-\frac{dE_0[y]}{dy_c} - \alpha E_0[y]\frac{f(y_c)}{F(y_c)}\right\} < 0, \tag{33}$$

such that all terms except for A_{y_c} can be unambiguously signed, implying that $D > 0$.

Note that

$$\frac{dE_0[y]}{dy_c} = f(y_c)\frac{y_c - E_0[y]}{F(y_c)} > 0 \tag{34}$$

$$\frac{dE_x[y]}{dy_c} = f(y_c)\frac{E_x[y] - y_c}{1 - F(y_c)} > 0. \tag{35}$$

We are interested in how $\hat{w}$ responds to an increase in the cut-off property value y_c. To answer this question, we must determine the sign of

$$D\frac{d\hat{w}}{dy_c} = -A_{y_c}B_{t_c} + B_{y_c}A_{t_c}, \tag{36}$$

where

$$\begin{aligned} -A_{y_c}B_{t_c} = &- \alpha s_0 E_0[y] t_c^{-1} f(y_c)\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} \\ &\times \left[s_0\left(\frac{t_c}{F(y_c)}\right)^{-\alpha}\frac{y_c - (1-\alpha)E_0[y]}{F(y_c)} + s_x\left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha}\frac{y_c - (1-\alpha)E_x[y]}{1 - F(y_c)}\right] \end{aligned} \tag{37}$$

and

$$\begin{aligned} B_{y_c}A_{t_c} = &\alpha s_0\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} f(y_c)\frac{y_c - (1-\alpha)E_0[y]}{F(y_c)} \\ &\times \left[s_0 t_c^{-1} E_0[y]\left(\frac{t_c}{F(y_c)}\right)^{-\alpha} + s_x(G(\hat{w}) - t_c)^{-1}E_x[y]\left(\frac{G(\hat{w}) - t_c}{1 - F(y_c)}\right)^{-\alpha}\right]. \end{aligned} \tag{38}$$

Returning to (36), we obtain

$$D\frac{d\hat{w}}{dy_c} = -\alpha s_0 s_x f(y_c)\left(\frac{t_c}{F(y_c)}\right)^{-\alpha}\left(\frac{G(\hat{w})-t_c}{1-F(y_c)}\right)^{-\alpha} \times \left[\frac{y_c E_0[y] - E_0[y]E_x[y](1-\alpha)}{(1-F(y_c))t_c} - \frac{y_c E_x[y] - E_0[y]E_x[y](1-\alpha)}{F(y_c)(G(\hat{w})-t_c)}\right]. \tag{39}$$

Accordingly, the condition $t_c/F(y_c) > (G(\hat{w}) - t_c)/(1 - F(y_c))$ is a sufficient condition for $d\hat{w}/dy_c > 0$, since the term in brackets is positive as long as

$$\frac{t_c/F(y_c)}{(G(\hat{w})-t_c)/(1-F(y_c))} > \frac{y_c E_0[y] - E_0[y]E_x[y](1-\alpha)}{y_c E_x[y] - E_0[y]E_x[y](1-\alpha)}, \tag{40}$$

where the right-hand side is less than one.