# "Inferiority"Complex? Policing, Private Precautions and Crime Brishti Guha<sup>1</sup>

# Abstract

I link the idea that greater state policing induces private neglect of safety precautions (moral hazard) with the concept of "inferior inputs" in the production function literature. I model crime prevention as an outcome of two "inputs" – policing (a public good) and private security expenses. I show that if cost-minimizing individuals choose insufficient private expenses to completely deter crimes, a rise in policing *raises* criminals' probability of success if and only if policing is an "inferior input" in crime prevention. This is so even though the marginal productivity of policing is always positive, and works through a strong moral hazard effect. I discuss implications for policy-makers.

JEL Classification: K42, D21, H41.

Keywords: Policing, crime, moral hazard, inferior inputs, private precautions, public goods.

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## **1. Introduction**

The Peltzman effect [Peltzman (1975)] refers to an empirically observed tendency of individuals to react to safety regulations by behaving in more risky ways, potentially offsetting the effect of the regulation on safety. In this paper I am concerned with a somewhat similar moral hazard problem in a different context – that of crime prevention. Apart from state policing, private security expenditure plays an important role in combating crime (Cook and Macdonald 2011, Ayres and Levitt 1998). Individuals or businesses hire private security guards or buy guns for self-defense; shippers have armed guards on board as an additional safety measure in spite of the presence of external anti-piracy patrols in pirate-infested waters. Will an increase in state policing generate moral hazard, discouraging such individual precautions against crime?<sup>2</sup> Indeed, can moral hazard be so severe that higher policing actually *raises* crime despite a positive marginal effect of policing on crime prevention? If so, when exactly will this happen?

To answer these questions I revisit a seemingly unrelated field, the literature on inferior inputs. This literature includes Bear (1965), Syrquin (1970) and Epstein and Spiegel (2000), among others. Very briefly, an input in a two-input production function is termed inferior if as output goes up, maintaining the same marginal rate of technical substitution between the two inputs requires a reduction in this particular input.<sup>3</sup> In the spirit of the production function literature, I model crime prevention as an "output" resulting from two inputs – state policing and private security expenses. In contrast to the inferior input literature which looks at privately chosen inputs, in my case, of the two inputs, policing is not chosen privately at all but is a public good. Individuals choose their optimal level of private security expenses taking policing as exogenous. I am unaware of any other applications of the idea of inferior inputs to crime.

I find that the extent and impact of moral hazard is critically linked to whether the "inputs" in crime prevention are inferior inputs. In particular, within a wide parameter zone where crimes are not completely deterred, greater policing results in *greater* success for criminals if and only if policing is an inferior input in crime prevention. This possibility reflects a strong moral hazard effect; the drop in private precautions induced by an increment in policing

 $<sup>^{2}</sup>$  That is, individuals may feel complacent ; increased police presence may make them feel that it is not necessary to take costly precautions for their safety. This is somewhat similar to the moral hazard that the insured may face.

<sup>&</sup>lt;sup>3</sup> This is discussed in more detail in Section 2.

may be so strong that effective security falls in spite of the rise in policing. The inferiority of the publicly provided input is associated with strong moral hazard. If, on the other hand, this input is normal, moral hazard, if any, will be too weak to offset the negative direct effect of policing on successful crime. Interestingly, I also find that whether or not cost-minimizing individuals take enough precautions to completely deter crimes is independent of the level of policing. I discuss implications for policy makers.

In addition to the papers already mentioned, this paper is connected to the subset of the literature which deals with potential victims' precautions against crime. This includes Shavell (1991), Ehrlich (1981), Clotfelter (1978), Hylton (1996), Lacroix and Marceau (1995), Friedman, Hakim and Spiegel (1987), Ben-Shahar and Harel (1995), Grechenig and Kolmar (2011), Clements (2003), Leeson (2007) and Guha and Guha (2012). Some of this literature, such as Shavell (1991), Ben-Shahar and Harel (1995), Clotfelter (1978) and Clements (2003), does not look at government provision of security at all, but asks instead whether the equilibrium level of private precautions against crime is socially optimal. Similarly Leeson (2007) models precautions taken by individual farmers expecting bandit attacks, but in a stateless society where by definition government policing is not a concern. The other literature does allow the state to play a role. Ehrlich (1981) restricts the government's role to fining criminals, and assumes that the government's actions do not affect private individuals' demand for precautions in the "market for offenses". My paper in contrast is focused on the interaction between public and private security. Friedman et al assume that "private security" is collectively consumed and also explicitly postulate that private and public security are additively separable. I assume neither collective consumption of private security nor separability between private and public security. Lacroix and Marceau (1995) model private precautions in a setting of incomplete information. Mine, in contrast, is a perfect information model.

More closely related is Guha and Guha (2012), to which the present paper is, in a sense, complementary. Guha and Guha (2012) concentrated on showing that moral hazard will *not* necessarily arise when the state provides greater policing. Unlike the present paper, which, in contrast, is focused on cases when moral hazard *does* arise, Guha and Guha (2012) was not concerned with input inferiority or normality. Also, unlike the present paper, it did not attempt to establish a theoretical link between the strength of the moral hazard effect and input inferiority; in particular, it did not consider how the crime rate might be affected by policing once these

effects are taken into account. The bulk of that paper considered two types of private precautions that individuals could take. One involved direct expenditure on security which reduced the probability of a criminal's success. The other, labeled "costly diversification", involved splitting up one's valuables into spatially separate lots so that each lot was too small to provoke a criminal attempt. In contrast, the present paper only considers direct security expenses.

Grechening and Kolmar (2011) focus on the equilibrium choice of private security, arguing that it should be regulated because it creates a moral hazard *on the part of the state*. The state, which, in their model, can commit to keeping anti-crime expenditures low, may supply too little policing because it thinks potential victims will compensate for low state policing through increased private precautions. They advocate regulating the level of private precautions under certain conditions. This is a very interesting complement to the current paper, which focuses instead on *private moral hazard* while treating state policing as exogenous. Unlike my paper, theirs does not apply the inferior input literature to crime, and nor does it obtain results about a positive relationship between state policing and criminals' success.

In addition to these, my paper is also related to the wider economics literature on deterrence.<sup>4</sup> Most of these papers study the causes or effects of organized crime or optimal prevention methods. Some literature has also empirically investigated the effects of greater policing on crime rates; an important example is Levitt (1997); a more recent one is Lin (2009). Many other empirical studies on the subject are surveyed in Cameron (1988).

Section 2 contains my model and results, while Section 3 concludes with a discussion.

### 2. A Model of Policing and Private Precautions

All agents – whether criminals or potential victims – have perfect information and are risk neutral. Potential victims can supplement government policing by spending directly on private security. Government policing G and private security expenditure x then combine to result in a certain probability p that a criminal attack fails and the criminal is apprehended:

$$\mathbf{p} = \mathbf{p} \left( \mathbf{G}, \mathbf{x} \right) \tag{1}$$

p is increasing and concave in both arguments:  $p_G>0$ ,  $p_x>0$ ,  $p_{GG}<0$ ,  $p_{xx}<0$ . Primarily, we focus on the case where x represents "substitutes" to policing in the sense that incurring x is relatively more effective in raising p when G, policing, is low:  $p_{xG}<0$ . For instance, private security guards

<sup>&</sup>lt;sup>4</sup> Including Stigler (1970), Schelling (1971), Anderson (1979), Reuter (1983,1987), Jennings (1984), Arlacki (1986), Jankowski (1991), Dick (1995), Konrad and Skaperdas (1998), Garoupa (2000), Polinsky and Shavell (2000), Skaperdas (2001), Chang, Lu and Chen (2005), Feess and Wolhschlegel (2009) and Miceli (2010).

are more useful in ill-policed areas. Guns may also be more useful when policing is insufficient. Ships on routes where anti-piracy patrols are sparse may find armed guards on board relatively more useful. We will also consider how our results are affected when x is "complementary" to policing, eg, expenditure on burglar alarms which work best when police response is rapid.

#### 2.1 Inferior Inputs and the cross-derivative condition

*Definition 1:* Consider a production function F(y,z). Then input z is an inferior input if the expansion path bends towards the axis along which input y is measured.

As output goes up, maintaining the same marginal rate of technical substitution between the two inputs requires a reduction in the inferior input. If the inferior input z is on the horizontal axis the curvature of the expansion towards the vertical axis implies that as y increases along any given vertical, the slope of the isoquant  $F_z/F_y$  falls. Now,  $\partial(F_y/F_z)/\partial y = [F_{yy}F_z - F_{yz}F_y]/(F_z)^2$ . Inferiority of z means that the numerator here is positive:  $F_{yy}F_z - F_{yz}F_y > 0$ .

We now translate this into the framework of our model. Here, instead of output, we are producing a given level of p according to (1). G and x are the "inputs" which result in a given level of p, a given probability of failure for criminals who launch an attack. However, while a producer in a firm chooses both his inputs, in our context individuals only choose private precautions x while policing G is exogenous to them. The fact that G is publicly provided does not affect the technical properties just mentioned. Measure G on the horizontal axis and x on the vertical. Applying the reasoning above, inferiority of G is equivalent to

$$p_{xx}p_G - p_{xG}p_x > 0 \tag{2}$$

I refer to (2) as the cross-derivative condition. Note that a negative cross-partial ie  $p_{xG}<0$  is necessary but not sufficient for the cross-derivative condition to hold, given  $p_{xx}<0$ ,  $p_G>0$ . If, however, x and G are sufficiently strongly substitutable, the condition holds and G is inferior. If G is never inferior, it is referred to as a "normal" input. G will always be normal if x and G are complementary in the sense of  $p_{xG}>0$ , as when x represents expenditure on burglar alarms.

Similarly, if x, not G, were an inferior input, the isoquants would get progressively steeper as G increased along any horizontal. The condition for inferiority of x is

$$p_{GG}p_x - p_{xG}p_G > 0 \tag{3}$$

Again, a negative cross-partial is necessary but not sufficient for (3) to hold; and if  $p_{xG}>0$ , x (as well as G) must be normal.

Before proceeding, we also note two results from the inferior inputs literature<sup>5</sup> which we will have occasion to use:

- (a) With a two-input production function, both inputs cannot be inferior.
- (b) At very small levels of output, both inputs are normal. However one input may become inferior as output reaches somewhat higher levels.

## 2.2 Private Precautions

Criminals know the "loot" value L that a potential target represents and can accordingly decide whether to attack. Normalizing criminals' outside option to 0 without loss of generality, they attack whenever their expected income from an attack is positive. Criminals are subjected to known penalties of S in the event their attacks are foiled – which happens with probability p – but manage to seize the loot L with probability 1-p, that is, in the event the attack succeeds. Thus, they attack if and only if

$$-p(G,x)S+(1-p(G,x))L>0$$

Or

$$p(G,x) > L/(L+S) \tag{4}$$

Now for any given level of policing G, a potential victim has two options, of which he chooses the cheaper. His first option is to deter attacks by choosing a level of private security  $x_0$  such that (4) holds as an equality at  $x = x_0$ . Thus we have

$$\mathbf{x}_0 = \mathbf{x} \{ \mathbf{G}, \mathbf{L}, \mathbf{S} \} \tag{5}$$

where  $x_0$  is increasing in L and decreasing in G and S.

Alternatively, he can choose a lower, non-deterrent level of private security  $\underline{x}$  to minimize expected losses – his expenses on security  $\underline{x}$  plus expected loss from a successful crime (in which event he loses L and incurs a cost of conflict  $\theta$  with probability  $1 - p(G, \underline{x})$ ). His optimization exercise is

 $\underset{x}{\text{Min}} \left\{ x + (1\text{-}p(G,x))(L+\theta) \right\}$ 

yielding the first order condition

$$p_{x}(G,\underline{x}) = 1/(L+\theta)$$
(6)

Alternatively we can write

$$\underline{\mathbf{x}} = \mathbf{x} \left( \mathbf{G}, \mathbf{L}, \mathbf{\theta} \right)$$
 (6')

<sup>&</sup>lt;sup>5</sup> See Bear (1965), Syrquin (1970).

He thus chooses  $\underline{x}$  if and only if

$$\underline{\mathbf{x}} + (1 - p(\mathbf{G}, \underline{\mathbf{x}}))(\mathbf{L} + \theta) < \mathbf{x}_0 \ (\mathbf{G}, \mathbf{L}, \mathbf{S})$$

$$\tag{7}$$

Fixing G,L, and  $\theta$ , individuals opt for a deterrent level of precautions when penalties are heavier than a threshold S\*, where (7) holds as an equality at S = S\*. This follows as we can verify that while the LHS of (7) is invariant to S, its RHS is decreasing in S.

*Proposition 1. The level of policing does not affect an individual's choice between a deterrent and a non-deterrent level of precautions.* 

*Proof:* Total differentiation of (5) with respect to x and G yields

$$dx_0/dG = -p_G/p_x \tag{8}$$

If policing increases, the level of private security required to achieve deterrence falls by (8), given  $p_G>0$ ,  $p_x>0$ . (8) shows the rate at which the RHS of (7) changes with G. We now verify the rate at which the LHS of (7) changes with G:

$$d\underline{x}/dG - (L+\theta) \{p_G + p_x d\underline{x}/dG\}$$

Substituting in for  $(L+\theta)$  from (6) and simplifying, the rate at which the LHS of (7) changes with G becomes

 $-p_G/p_x = dx_0/dG.$ 

Both sides of the inequality change at the same rate with G. Thus, choice between a deterrent and a non-deterrent level of precautions is independent of the actual level of policing. *QED* 

I now refer to the parameter zone where deterrence is preferred as the "deterrence zone" and the one where a non-deterrent level of precautions is chosen as the "no-deterrence zone". From the reasoning above, one can be in the no-deterrence zone when, for instance, criminal penalties are not very heavy, as this makes it very expensive to deter criminals.<sup>6</sup> As some crime does exist in reality, it can be argued that the no-deterrence zone represents the empirically more realistic case, and therefore I concentrate on it below.<sup>7</sup>

# 2.2.1 The No-Deterrence Zone

Proposition 2: Suppose individuals optimally choose a non-deterrent level of precautions. Then a rise in policing **increases** the probability of success of a criminal attack over a certain range if

<sup>&</sup>lt;sup>6</sup> For instance, this is typically the case with modern-day pirates. Penalties for captured pirates tend to be light; indeed many are simply released after confiscation of weapons. This is done in the interests of avoiding complications associated with international law (Kontorovich 2010).

<sup>&</sup>lt;sup>7</sup> Results on the deterrence zone are available on request.

and only if policing is an inferior input into security in that range. This happens even though policing has positive marginal productivity throughout.

*Proof:* Individuals choose a non-deterrent level of precautions  $\underline{x}$ . To see how private precautions respond to a rise in policing, we totally differentiate (6) with respect to x and G, obtaining

$$d\underline{\mathbf{x}}/d\mathbf{G} = -\mathbf{p}_{\mathbf{x}\mathbf{G}}/\mathbf{p}_{\mathbf{x}\mathbf{x}} \tag{9}$$

Given  $p_{xx}<0$ , and  $p_{xG}<0$  (since we are focusing on the case where private security is substitutable with, rather than complementary to, policing<sup>8</sup>), we see that private precautions are optimally reduced when policing increases. From (6), they adjust so as to keep  $p_x$  – the marginal efficacy of private security – constant. Now, the overall effect of a rise in policing dG on p is

$$dp = p_G dG + p_x dx$$

or

$$dp = [p_G - p_x(p_{xG}/p_{xx})]dG \text{ (using (9) or}$$
$$dp = [(p_{xx}p_G - p_{xG}p_x)/(p_{xx})]dG$$
(10)

Given  $p_{xx}<0$ , we note that dp/dG <0 if and only if  $p_{xx}p_G-p_{xG}p_x >0$ . But from (3), this is exactly the condition for G to be inferior. Therefore, p falls or criminals' probability of success goes up with an increment in policing if and only if policing is an inferior input over the relevant range. This happens even though we have  $p_G>0$ . Note that if x and G are complementary rather than substitutable, increases in policing will always be associated with higher p (lower probability of criminals' success) since in that case G is necessarily normal. *QED* 

What is the intuition underlying Proposition 2? When policing increases, it has a direct marginal effect on p, which is positive. However, it also has an indirect effect which works through the response of private precautions to the rise in policing. Individuals adjust their costminimizing level of precautions to G in such a manner as to keep the marginal efficacy of x constant. Now, if x and G are substitutes, a rise in G reduces the marginal efficacy of x. Given diminishing marginal efficacy of x, this then requires a reduction in x to maintain the old level of marginal efficacy. Thus there is a "moral hazard" effect; precautions drop when policing increases. The drop in precautions in itself has a dampening effect on p. When x and G are sufficiently strong substitutes, that is, when G is inferior so that the cross-derivative condition (3) obtains, this indirect effect overpowers the direct effect of a rise in G on p. Therefore, even

 $<sup>^{\&</sup>amp;}$  If on the other hand x represents complementary expenditure such as on burglar alarms, such expenditure actually goes up with a rise in policing.

though policing in itself is always productive, a rise in it causes security to actually fall, raising the probability of criminals' success over the relevant range.

Mathematically, note that even with  $p_{xG}<0$ , we may not have  $p_{xx}p_G-p_{xG}p_x>0$  if  $p_{xx}$  is very large in absolute value. The intuition here is that if the marginal efficacy of x diminishes at a very rapid rate, then a relatively small reduction in x is sufficient to restore  $p_x$  to its original level when G goes up. This would then make the indirect effect noted above relatively small, so that the overall effect of policing on p would then be positive.

#### 2.3 Results over different ranges of security p

We now use the result from the inferior inputs literature noted above that while both inputs are normal at very small levels of output, one input may become inferior as output reaches somewhat higher levels. Consider an example where when p is very low, both x and G are normal. However, G becomes inferior when p reaches a threshold <u>p</u>. Moreover, assume that p < L/(L+S)so that security at this threshold is insufficient to deter criminals.

Observation 1. For the example above, if individuals choose a non-deterrent level of precautions (as when penalties are not too heavy), increments in policing reduce criminals' probability of success 1-p when their rates of success are above 1-p, but increase criminals' probability of success when these success rates fall below this threshold. If individuals choose a deterrent level of precautions, then moral hazard weakens as policing goes up.

Observation 1 follows directly from the results in the previous sections. Thus, in the nodeterrence zone, when effective security is so low that criminals have a high probability of success, policing succeeds in reducing successful crime. However, when the security situation improves so that criminals are no longer as successful, then in spite of policing in itself always being productive, rises in policing may begin to increase rather than reduce criminals' success. This effect sets in because policing may become inferior over this range, so that the indirect effect via moral hazard overpowers the direct impact of greater policing on criminals' success.

An interesting implication of Observation 1 is that for this example, in the no-deterrence zone the probability of foiling criminals p always converges to  $\underline{p}$  as policing increases.<sup>9</sup>

<sup>&</sup>lt;sup>9</sup> This follows as policing is inferior for p>p (and so p falls with G in this domain) while for p<p policing is normal, so that p rises with G within this domain.

### **3.** Conclusion and Policy Implications

I apply the theory of inferior inputs to the problem of moral hazard in crime prevention. I model crime prevention as an outcome resulting from two inputs, one of which, policing, is state-supplied, while the other, private security expenses, is chosen privately and vulnerable to moral hazard. Individuals decide on their cost-minimizing level of private precautions. Interestingly, their choice of whether to take enough precautions to completely ward off criminal attacks, rather than opting for a lower, non-deterrent level of private precautions, is unaffected by the level of policing. In the zone of non-deterrence, I find that an increase in policing *increases* criminals' success if and only if policing is an inferior input in crime prevention. This stems from strong moral hazard; individuals reduce their private precautions so sharply in response to a rise in policing as to depress effective security. If policing is a normal input, then although moral hazard may set in if a rise in policing reduces the marginal efficacy of private security, this effect is weak relative to the direct negative impact of policing on crime.

These results suggest that the overall impact of police on crime rates is not necessarily a reflection of actual police efficacy in combating crime. There is also an indirect effect working through the interaction between policing and private precautions. The implications for policing are nuanced. As long as there is some crime (so that we are in the no-deterrence zone), a policy maker has to be aware whether a significant portion of individuals' private security expenses are incurred on items whose marginal efficacy in combating crime falls<sup>10</sup>, rather than increases, with policing over a certain range. For example, do individuals spend relatively more on private security guards, or guns for self-defense, rather than on burglar alarms, as policing goes up? If so, then increasing policing over the relevant range may be counterproductive in terms of the impact on crime rates. This would be particularly so if the items of private security expenditure displayed weakly diminishing marginal efficacy. Thus policy makers might not want to implement measures increasing police presence under these circumstances.<sup>11</sup> On the other hand, if security expenses were largely incurred on items whose marginal efficacy *rises* with policing, this problem would not arise.

<sup>&</sup>lt;sup>10</sup> This being a necessary condition for inferiority.

<sup>&</sup>lt;sup>77</sup> This does not imply, however, that police presence should be reduced to zero, or that offences should be decriminalized. The reason for this is that policing is not going to be an inferior input at all crime levels or all levels of policing. If police were reduced to zero, one would enter the zone where policing is a normal, rather than an inferior input, and crime would go up.

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