When do more police induce more crime?*

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Abstract

We provide a necessary and sufficient condition on the equilibrium of a Walrasian economy for an increase in police expenditure to induce an increase in crime. It turns out that this is essentially the condition for the Laffer curve to be downward sloping at a given ad valorem tax rate. Notably, such a perverse effect of police on crime is consistent with any appropriation technology and could arise even if the level of police protection is the socially optimal one.

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1 Introduction

One of the more longstanding questions in the empirical literature on crime concerns the extent to which police affects crime.[1] While early papers have struggled to find a negative causal relation between police and crime, the more recent literature has managed to identify several instances in which this causality manifests itself.[2] The main difficulty stemmed from the fact that while criminals may well react to an increase in police presence, police also tend to be deployed where there is crime.

Despite being vast, the empirical literature on crime and police seems to stand on quite modest theoretical foundations. As Burdett, Lagos, and Wright (2003) aptly say, "much (although not all) work on the economics of crime uses partial equilibrium reasoning or empirical methods with very little grounding in economic theory." One of the possible reasons for this meager theoretical support is that models of crime are somewhat scarce. Indeed, Polinsky and Shavell (2000) and Chalfin and McCrary (2017), two recent surveys on law enforcement and deterrence, are centered exclusively on a simplified version of Becker's (1968) seminal model. Furthermore, most of the empirical papers that investigate the causal effect of police on crime do not explicitly formulate the structural model on which they are based, thereby making it difficult to make out the mechanism through which police may affect crime.

Although early economists were aware of the importance of theft as an allocation process, not until the 1960s was crime formalized as an economic activity performed

[1] Prominent exponents of this literature are Marvell and Moody (1996), Levitt (1997), Evans and Owens (2007), Di Tella and Schargrodsky (2004), Klick and Tabarrok (2005), Draca, Machin, and Witt (2011), Chalfin and McCrary (2018) and, more recently, Weisburd (2021), and Bindler and Hjalmarsson (2021). See also Levitt and Miles (2006) and Chalfin and McCrary (2017) for additional references.

[2] Still this relationship seem to depend, among other things, on the type of crime. For instance, while Bindler and Hjalmarsson (2021) finds evidence that the creation of the London Metropolitan Police has indeed reduced violent crime, a reduction of property crime is not visible.

by rational agents. Since Becker (1968), several strands of literature that adopt the economic approach to the study of crime have emerged. Early papers use models in which consumers and criminals react to incentives and meet in the proverbial market for offenses (see Ehrlich (1996) for an overview). Another strand of literature adopts a game theoretic approach. See Garfinkel and Skaperdas (2007) for some references. While most of this literature models criminals and victims as big players, in a recent paper, Vásquez (2022) models them as small players that jointly determine the level of crime and vigilance. Other papers adopt a search-theoretic approach to model an economy with theft, prominent examples being Burdett, Lagos, and Wright (2003, 2004). Finally, a few papers introduce theft into a Walrasian model, notably Usher (1987), Grossman (1994), Dal Bó and Dal Bó (2011), and Lasso de la Vega, Volij, and Weinschelbaum (2021).

Except for Lasso de la Vega, Volij, and Weinschelbaum (2021), and Vásquez (2022), a noteworthy attribute of the above models is that they predict that law enforcement unequivocally deters crime. The models that follow Becker's approach assume that the supply of criminal offenses is negatively related to the probability of apprehension. The search model proposed by Burdett, Lagos, and Wright (2003) exhibits multiple types of equilibria, all of which predict that police reduce crime. The same prediction arises from the model in Dal Bó and Dal Bó (2011). The reason is that in these models, while the relevant endogenous variables affect the level of crime, the level of crime does not have any feedback effect on the other variables.

Lasso de la Vega, Volij, and Weinschelbaum (2021) shows that when theft is introduced in a Walrasian model in a way that allows all factors of production to be stealable, more police unequivocally reduce crime. But when only produced goods are subject to theft, an example is provided in which an increase in police actually increases crime. In this paper, we show that such a perverse effect of police on crime is not due to unrealistic primitives of the economy that lead to a pathological example. Rather, we provide a necessary and sufficient condition on the equilibriun for the police to have a perverse effect on crime. Interestingly, this condition is essentially the condition for the Laffer curve to be downward sloping at a given ad valorem tax rate. The reason is the following. In our model, crime acts as an ad-valorem tax on consumption goods, and in equilibrium, the corresponding tax revenue equals the level of crime. An increase in police unambiguously reduces the "tax rate" and thus, whether the level of crime rises or not depends on a particular relationship between the equilibrium tax rate and the elasticities of demand and supply. This relationship turns out to be precisely the well-known condition for the Laffer curve to be decreasing.

One may wonder if the above-mentioned condition is overly restrictive. We show that this is not the case by proving that, for any set of values of the endogenous variables, it is possible to calibrate an economy that fits them and whose unique equilibrium satisfies the condition. It could be objected that the calibrated economy endows thieves with a very special appropriation technology.[3] However, we also show that for any appropriation technology, one can build an economy with a Cobb-Douglas production function and CRRA preferences such that an increase in police protection induces an increase in crime. The mechanism is based on the fact that whereas, *coeteris paribus*, more police have a negative incentive on thieves, it also promotes economic activity which in turn makes theft more profitable. When the latter effect is strong enough, the perverse effect of police on crime arises.

One may also object that once a model allows for general equilibrium effects anything is possible. In particular, it may not be at all surprising that in such a model police increases crime. Our main result shows, however, that even accounting for feedback effects of crime on markets, whereas an increase in police spending may raise property crime, it unequivocally decreases the share of the GDP that is ultimately stolen. Hence, not anything goes.

One may still wonder whether the perverse effect of police on crime stems from

[3]The appropriation technology describes the relationship between the resources devoted to theft, police presence, and the size of the booty.

a suboptimal level of police protection. For instance, Chalfin and McCrary (2018) suggest that "additional investments in police are unlikely to be socially beneficial unless police reduce violent crimes to at least a moderate degree." We show, however, that it may well be the case that even at the optimal level of police protection a perverse effect of police on crime still emerges. In particular, even though less police induces less crime, it is not socially worthwhile to reduce police spending. The reason is that one of the consequences of lower police protection is a decrease in output whose social cost may outweigh the benefits of lower crime and less police spending.

One final comment on our measure of crime. In this paper crime is measured by the aggregate amount of time devoted to theft. Since in our model crime is equivalent to theft, an alternative measure of crime would be the value of the stolen goods. It turns out that in equilibrium, these two measures are equivalent. This equivalence makes them the natural measure of crime.

The rest of the paper is organized as follows. Section 2 introduces the model and characterizes its competitive equilibrium. Section 3 establishes our main results. Finally, Section 4 concludes and makes a brief comparison with Vásquez (2022).

2 The model

We now present a variation of the general equilibrium model with theft introduced by Lasso de la Vega, Volij, and Weinschelbaum (2021), under the assumption that only produced goods are subject to theft. The primitives of the model are the following. There is a publically available technology that transforms capital and labor into a consumption good, which will be henceforth referred to as *peanuts*. This technology is described by a constant returns to scale, monotone and concave production function $F(K, L)$. There is a continuum of individuals $I = [0, 1]$, characterized by an initial endowment of capital $\overline{k}_i$ and labor $\overline{l}_i$, and a quasilinear utility function $u_i(x, \ell) = \phi_i(x) + \ell$, that depends on the amount of peanuts, x, and leisure, ℓ, consumed. We assume that ϕ_i is strictly increasing, concave, and that $\lim_{x\to\infty} \phi_i'(x) = 0$. For notational convenience we will assume that all individuals are identical, namely $\phi_i = \phi$, $\overline{k}_i = \overline{K}$ and $\overline{l}_i = \overline{L}$ for all $i \in [0,1]$. Furthermore, to avoid dealing with boundary problems, we assume that individuals can consume negative amounts of leisure and that the production function satisfies the Inada conditions. In particular, $\lim_{L\to 0} F_2(K,L) = \infty$.[4]

There is an appropriation sector that uses labor to redistribute output from earners to thieves. Following Grossman (1994) and Dal Bó and Dal Bó (2011), we describe the appropriation technology by a function $A : \mathbb{R}^2_+ \to [0,1]$. The value $A(Y,T)$ is the proportion of the individuals' income that gets stolen when the crime level is Y and police protection T. We call $A(Y,T)$ the *excise rate of theft* associated with Y and T. We assume that $A(0,T) = 0$, that A is increasing and strictly concave in its first argument, decreasing and strictly convex in its second argument, and that $A_{12} < 0$, namely the marginal excise rate of crime is decreasing in police protection. These assumptions imply that

$$A_1(Y,T) < \frac{A(Y,T)}{Y}$$

and that $\lim_{Y\to 0} A(Y,T)/Y = A_1(0,T)$. Namely, the marginal excise rate is lower than the average excise rate. We denote by $a(Y,T)$ the *average excise rate*, with the extension $a(0,T) = A_1(0,T)$. It is the proportion of wealth stolen per unit of time devoted to theft. It follows from our assumptions that $a(Y,T)$ is decreasing in both its arguments, and convex in its second argument. We summarize the data of the economy by $\mathcal{E} = \langle(\phi, \overline{K}, \overline{L},), F, A, T\rangle$.

Individuals, apart from consuming peanuts and leisure, devote some time to theft. A *bundle* for individual i is thus a triple $(x_i, \ell_i, y_i) \in \mathbb{R}_+ \times \mathbb{R} \times \mathbb{R}_+$ whose components are the amounts of peanuts, leisure, and time devoted to theft. We denote the set of bundles by $\mathcal{X}$.

[4] For any function $f : \mathbb{R}^2 \to \mathbb{R}$, we denote by f_1 and f_2 its partial derivatives with respect to its first and second arguments. Also f_{jk}, for $j,k = 1,2$, stand for the corresponding second derivatives.

We assume that all individuals are equally effective at stealing. Consequently, when individual i devotes y_i units of his time to theft, the crime level is $Y = \int_0^1 y_i di$, and he gets a portion y_i/Y of the booty.[5,6] There is a level T of public police protection which is allocated uniformly across individuals and is financed by means of compulsory taxation.

An *allocation* in $\mathcal{E}$ consists of an input pair $(K, L) \in \mathbb{R}^2_+$, an assignment $(x, \ell, y) : [0, 1] \to \mathcal{X}$ of bundles to individuals, and a crime level Y. An allocation is *feasible* if

$$\begin{aligned} \int x &= F(K, L) \\ \overline{L} &= \int \ell + L + \int y + T \\ \overline{K} &= K \\ Y &= \int y. \end{aligned} \tag{1}$$

Namely, peanuts consumed are equal to peanuts produced, the sum of time devoted to leisure, labor, theft and police protection equals the total time available, capital used in the production process equals the amount of capital available, and the crime level is the per capita time devoted to theft.

2.1 Competitive equilibrium

We normalize the wage rate to be 1, denote the price of peanuts by p, and for simplicity, we assume that public police is financed by uniform taxation. The resources that an individual has available for the purchase of peanuts consist of the

[5]If agents were heterogeneous regarding their stealing capabilities, the crime level would be a weighted average of the time spent on theft by the agents, with weights being the respective capabilities. In this case, the share of the booty obtained by an individual would be proportional to the time devoted to theft weighted by his capability. Nothing substantial would be gained by this assumption.

[6]For any real function f defined on $[0, 1]$, we will sometimes write $\int f$ for $\int_0^1 f_i \, di$. All functions defined on $[0, 1]$ are assumed to be integrable.

portion of his legitimate income (net of taxes) that is not stolen, plus the proceeds from his appropriation activities. His legitimate income consists of his labor income, $\overline{L}-\ell_i-y_i-T$, and his capital income, $r\overline{K}$. The portion of this legitimate income that is saved from the claws of thieves is, therefore, $(1-A(Y,T))(r\overline{K}+\overline{L}-\ell_i-y_i-T)$. Aditionally, under our assumption that only produced goods are subject to theft, the returns to theft are given by $a(Y,T)pF(\overline{K},L)$. Therefore, the proceeds from his appropriation activities are $y_i a(Y,T)pF(\overline{K},L)$. As a result, individual i's budget is given by

$$\left\{(x_i,\ell_i,y_i) : px_i \leq (1-A(Y,T))(r\overline{K}+\overline{L}-\ell_i-y_i-T)+y_i a(Y,T)pF(\overline{K},L)\right\}$$

The parameters that the individual takes as given are the price of peanuts p, the rental rate of capital r, the tax T, the crime level Y, and the returns to theft.[7] Also note that the relative price of peanuts (in terms of leisure) faced by the consumers is $p/(1-A(Y,T))$. This is so because if a consumer wants to bring home one unit of peanuts he needs to buy $1/(1-A(Y,T))$ units, since a proportion $A(Y,T)$ of them will be stolen.

The concept of competitive equilibrium is the usual one.

Definition 1 A *competitive equilibrium* consists of a price of peanuts p^*, a rental rate of capital r^*, and a feasible allocation $\langle (L^*,K^*),(x^*,\ell^*,y^*),Y^*\rangle$, such that

1. The input pair (L^*,K^*) maximizes profits given p^* and r^*.
2. For all $i \in [0,1]$, the bundle (x_i^*,ℓ_i^*,y_i^*) maximizes the individual's utility given p^*, r^*, and Y^*.

2.2 Characterization of the equilibrium

Given our assumptions on preferences and technology, any equilibrium allocation $\langle (L^*,K^*),(x^*,\ell^*,y^*),Y^*\rangle$ must satisfy $K^*>0$, $L^*>0$ and $x^*>0$. Therefore, the

[7]We ignore his share in the firms' profits since, given the constant returns to scale technology, profits will be 0 in equilibrium.

necessary (and sufficient) conditions for profit maximization are:

$$\begin{aligned} p^* \frac{\partial F}{\partial L}(K^*, L^*) &= 1 \\ p^* \frac{\partial F}{\partial K}(K^*, L^*) &= r^* \end{aligned}$$

Namely, input prices must be equal to the value of their marginal productivity.

The first-order conditions for individual i's utility maximization are:

$$\phi'(x_i^*) = \frac{p^*}{1 - A(Y^*, T)} \tag{2}$$

$$1 - A(Y^*, T) \geq a(Y^*, T) p^* F(K^*, L^*) \quad \text{with equality if } y_i^* > 0 \tag{3}$$

$$p^* x_i^* = (1 - A(Y^*, T))(r^* \overline{K} + \overline{L} - \ell_i^* - T) \tag{4}$$

where Y^* is the crime level associated with the equilibrium allocation. Observe that in equilibrium $A(Y^*, T) < 1$, which follows from (2). Condition (3) is an arbitrage condition which states that the returns to theft cannot exceed the returns to labor, and that they must be equal if the individual devotes positive time to theft.[8]

Finally, the allocation must satisfy the feasibility conditions (1).

Given that in equilibrium, the capital used by the firms, K^*, must be $\overline{K}$, it will be convenient to define the firm's short-run supply function.[9] It is the function $Q : \mathbb{R}_{++} \to \mathbb{R}_+$ implicitly defined by

$$\begin{aligned} 1 &= p \frac{\partial F}{\partial L}(\overline{K}, L) \\ Q(p) &= F(\overline{K}, L) \end{aligned}$$

Similarly, it will be convenient to define the economy's aggregate demand function for peanuts. It is the function $X : \mathbb{R}_{++} \to \mathbb{R}_+$ implicitly defined by

$$\phi'(X(p^d)) = p^d$$

[8] Given that individuals are homogeneous in their appropriation capabilities, all of them may engage in theft. If they were heterogeneous, their respective returns to theft would be proportional to their capabilities, and only the most effective thieves would engage in theft.

[9] We call it short-run supply because capital is restricted to be fixed at $\overline{K}$. If the firm were free to choose any level of capital, since the technology exhibits constant returns to scale, the supply would be perfectly elastic.

where p^d denotes the price faced by the consumers.

Upon close observation of the above equilibrium conditions, and taking advantage of the definitions of the short-run aggregate supply and demand functions just defined, we can see that to find an equilibrium it is enough to solve

$$1 - A(Y,T) \geq a(Y,T)pQ(p) \quad \text{with equality if } Y > 0 \tag{5}$$

$$X\left(\frac{p}{1 - A(Y,T)}\right) = Q(p) \tag{6}$$

This is a system of two equations with two unknowns (p and Y). Once solved, the other variables are obtained by mere substitution. Indeed, x_i^* and ℓ_i^* are obtained from equations (2) and (4), and the remaining variables, L^* and r^* are directly obtained from

$$\begin{aligned} F(\overline{K}, L^*) &= Q(p^*) \\ p^* \frac{\partial F}{\partial K}(\overline{K}, L^*) &= r^* \end{aligned}$$

Note that whereas L^* and Y^* are determined in equilibrium, the time devoted by individual i to labor and to theft is not. We only know that the time devoted to labor and theft combined is $\overline{L} - T - \ell_i^*$.

Note that in equilibrium

$$Y^* = \frac{A(Y^*,T)}{1 - A(Y^*,T)} p^* Q(p^*). \tag{7}$$

Indeed, if $Y^* = 0$, this equality is trivially satisfied. And if $Y^* > 0$, it follows from (5). Recall that $p^*/(1 - A(Y^*,T))$ is the peanut price faced by the consumers. Therefore, the above equation says that in equilibrium, the aggregate time devoted to theft equals the value of the stolen goods at consumer prices. For that reason, it is natural to call Y^* the level of theft or of (property) crime. The relationship in equation (7) appears in other models of theft, Dal Bó and Dal Bó (2011) to name just one. See also footnote 3 in Becker (1968). It is an expression of the more general phenomenon whereby the market value of the inputs devoted to the exploitation of a common resource by infinitesimally small agents with equal productivity is equal to the value of the common resource extracted. The reason is that these agents will invest inputs until their unit returns are equated to the market value of a unit of input. Since in the exploitation of a common resource, each unit of input obtains the average product, the value of the inputs equals the value of the resources extracted.

Also note that it follows from equation (7) that

$$Y^* = \frac{A(Y^*,T)}{1 - A(Y^*,T)} p^* Q(p^*) = A(Y^*,T)p^*Q(p^*) + A^2(Y^*,T)p^*Q(p^*) + \cdots$$

That is, property crime at the equilibrium crime level Y^* is not just the proportion $A(Y^*,T)$ of the GDP. This portion, $A(Y^*,T)p^*Q(p^*)$, is only the peanuts stolen from the income legitimately earned by the agents. But property crime includes also the peanuts stolen from the stolen income as well, and so on.

Figure 1 depicts the equilibrium in the peanut market (where $A(Y^*,T)$ is denoted simply by A^*).

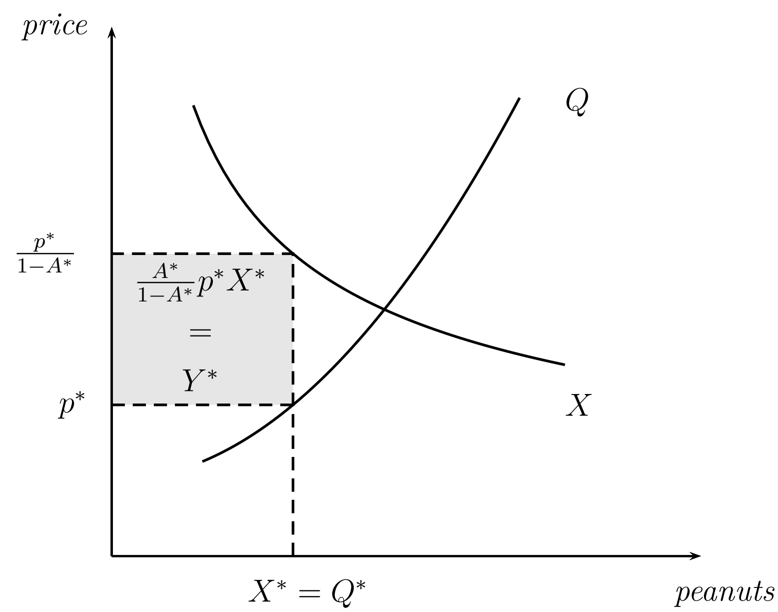

Figure 1: The peanut market.

The price faced by the consumers is $p^*/(1-A(Y^*,T))$ and the price faced by the firm is p^*. The difference is $p^*\frac{A(Y^*,T)}{1-A(Y^*,T)}$. As can be seen, theft has a similar effect to that of an ad valorem tax of $A(Y^*, T)/(1 - A(Y^*, T))$. It introduces a wedge between the effective price paid by the consumers and the one received by the firm. The difference is the value of the peanuts being stolen when one unit of peanuts is acquired. However, since by (7), the value of the stolen peanuts equals the value of the time spent on appropriation activities, this value ultimately dissipates.

Lasso de la Vega, Volij, and Weinschelbaum (2021) shows that there are economies with no equilibrium. However, it also shows that if the appropriation technology satisfies certain weak conditions, an equilibrium exists and is unique. This is stated in the following observation. Since it is short, we include a proof that fits this version of the model.

Observation 1 Let $\mathcal{E} = \langle(\phi, \overline{K}, \overline{L},), F, A, T\rangle$ be an economy. Then, if the appropriation technology A is bounded away from one, an equilibrium exists. If, furthermore, $\frac{a(Y,T)}{1-A(Y,T)}$ is non-increasing in Y, the equilibrium is unique.

Proof : See Appendix. □

For future reference, we define $g(Y, T) = \frac{a(Y,T)}{1-A(Y,T)}$. Given our assumptions on A, the function g satisfies $g_2 < 0$. Appropriation technologies A that are bounded away from one and for which $g(Y, T)$ is non-increasing in Y are said to be *regular*.

3 The effect of police on crime

We want to now focus on the effect of police protection on the crime level. It can be seen from equations (5–6) that the peanut market affects the crime level and simultaneously the crime level affects the peanut market. For that reason, the effect of changes in police protection on crime may be ambiguous. If we observe Figure 1 we see that an increase in crime is reflected in the growth of the shaded area. Therefore, we can expect that the perverse effect of police on crime will occur if certain conditions on the elasticites of demand and supply are met. The next theorem establishes these conditions.

Theorem 1 Consider an equilibrium of an economy in which police expenditure is T_0. If the equilibrium crime level Y^* is positive, and $g_1(Y^*, T_0) \leq 0$, then

1. an increase in police protection induces an increase in the equilibrium peanut price, $p(T_0)$, and output, $Q(p(T_0))$;

2. an increase in police protection induces a decrease in the equilibrium excise rate, $A(Y^*, T_0)$, and crime's implied tax rate of peanuts $A(Y^*, T_0)/(1 - A(Y^*, T_0))$;

3. an increase in police protection induces an increase in crime if and only if

$$A(Y^*, T_0) > \frac{(\varepsilon - \eta)}{(1 + \eta)\,\varepsilon} \tag{8}$$

where η and ε are the elasticity of the supply function Q at p^* and of the demand function X at $p^*/\left(1 - A(Y^*, T_0)\right)$, respectively.

Proof : Recall that $g(Y,T) = \frac{a(Y,T)}{1-A(Y,T)}$ and notice that any equilibrium of an economy $\mathcal{E} = \langle(\phi, \overline{K}, \overline{L},), F, A, T_0\rangle$ with positive crime level Y^* and peanut price p^* is characterized by

$$\begin{aligned} 1 &= g(Y^*, T_0) p^* Q(p^*) && (9) \\ X\Big(\frac{p^*}{1 - A(Y^*, T_0)}\Big) &= Q(p^*). && (10) \end{aligned}$$

These equations implicitly define the equilibrium crime level $Y(T)$ and peanut price $p(T)$ as functions of police protection in a neighborhood of T_0, with $Y(T_0) = Y^*$ and $p(T_0) = p^*$. By the implicit function theorem

$$\begin{aligned} p'(T_0) &= \frac{p^* Q X' \left(A_2 g_1 - A_1 g_2\right)}{X' g A_1 \left(p^* Q' + Q\right) + (1 - A) g_1 Q \left((1 - A) Q' - X'\right)} && (11) \\ Y'(T_0) &= -\frac{X' g A_2 \left(p^* Q' + Q\right) + (1 - A) g_2 Q \left((1 - A) Q' - X'\right)}{X' g A_1 \left(p^* Q' + Q\right) + (1 - A) g_1 Q \left((1 - A) Q' - X'\right)} && (12) \end{aligned}$$

where we have used the following simplifying notation: $g = g(Y^*, T_0)$, $g_1 = g_1(Y^*, T_0)$, $g_2 = g_2(Y^*, T_0)$, $A = A(Y^*, T_0)$, $A_1 = A_1(Y^*, T_0)$, $A_2 = A_2(Y^*, T_0)$, $Q = Q(p^*)$, $Q' = Q'(p^*)$, and $X' = X'(\frac{p^*}{1-A(Y^*,T_0)})$. Recall that in equilibrium $A(Y^*, T_0) < 1$ and hence these values are well defined.

Given our assumptions on the appropriation technology and that $g_1(Y^*, T_0) \leq 0$, we have that the denominator of the above expressions is negative and the numerator of (11) is negative as well. Therefore, $p'(T) > 0$. As a result, since $Q'(p) > 0$, we also obtain that the equilibrium level of output is increasing in T. This proves the first part of the theorem.

Also, we have

$$\begin{aligned} \frac{dA}{dT} &= A_1 Y'(T) + A_2 \\ &= \frac{(1-A)Q\left(A_2 g_1 - A_1 g_2\right)\left((1-A)Q' - X'\right)}{X' g A_1\left(p^* Q' + Q\right) + (1-A) g_1 Q\left((1-A)Q' - X'\right)} \end{aligned}$$

which, given the properties of g and A, can be checked to be negative. This implies that the ratio $A/(1-A)$ is also decreasing in T, which proves the second part of the theorem.

Since the denominator of (12) is negative,

$$\begin{aligned} Y'(T_0) > 0 \Leftrightarrow \quad & -X' g A_2\left(p^* Q' + Q\right) && < && (1-A) g_2 Q\left((1-A)Q' - X'\right) \\ \Leftrightarrow \quad & -X' \frac{A}{Y^*(1-A)} A_2\left(p^* Q' + Q\right) && < && (1-A)\frac{A_2}{Y^*(1-A)^2} Q\left((1-A)Q' - X'\right) \\ \Leftrightarrow \quad & -X' A A_2\left(p^* Q' + Q\right) && < && A_2 Q\left((1-A)Q' - X'\right) \\ \Leftrightarrow \quad & -X' A\left(p^* Q' + Q\right) && > && Q\left((1-A)Q' - X'\right) \end{aligned}$$

where we have used the fact that $g_2 = A_2/(Y^*(1-A)^2)$ and that $A_2 < 0$. Dividing both sides by Q, and denoting by η the elasticity of the supply function at p^*, we obtain that $Y'(T_0) > 0$ if and only if

$$-X' A\,(1+\eta) > (1-A)Q' - X'.$$

Multiplying both sides by $p^*/\left(Q(1-A)\right)$, and taking into account that in equilibrium $Q = X$, we obtain

$$-\frac{X'}{X}\frac{p}{(1-A)}A(1+\eta) > p\frac{Q'}{Q} - \frac{X'}{X}\frac{p}{(1-A)}.$$

Denoting by ε the elasticity of the demand function X at $p^*/(1 - A(Y^*, T_0))$, the above inequality can be written as

$$-\varepsilon A(1+\eta) > (\eta - \varepsilon)$$

which holds if and only if

$$1 > A > \frac{(\varepsilon - \eta)}{(1+\eta)\varepsilon}$$

which proves the third statement of the theorem. □

The third part of Theorem 1 says that the effect of police on crime is ambiguous; under certain conditions more police induces more crime and under other conditions reduces crime. It could be argued that this is not surprising since once general equilibrium effects are allowed, anything can happen. However, as the first and second parts of the theorem show, even with feedback effects an increase in police expenditure unambiguously increases the price and quantity of peanuts and reduces the equilibrium excise rate. Therefore, the above ambiguity is not a forgone conclusion.

Theorem 1 states that a necessary and sufficient condition for the police to have an adverse effect on crime is that the equilibrium excise rate be bigger than $\frac{(\varepsilon-\eta)}{(1+\eta)\varepsilon}$. It can be checked that, since $A < 1$, this inequality implies that $\varepsilon < -1$. This means that a sufficient condition for the police to reduce crime is that the demand for peanuts be inelastic. Condition (8) can be equivalently written as

$$0 < \frac{\varepsilon - \eta}{\eta(1+\varepsilon)} < \frac{A(Y^*, T_0)}{1 - A(Y^*, T_0)}. \tag{13}$$

Recall that $t^* = \frac{A(Y^*,T_0)}{1-A(Y^*,T_0)}$ is the ad valorem "tax rate" imposed by crime on peanuts. Condition (13) is precisely the condition for the Laffer curve to be downward sloping at the ad valorem tax rate of t^*. The intuition for this equivalence is the following. As the second part of Theorem 1 shows, an increase in police expenditure unambiguously results in a reduction in crime's tax rate, t^*, on peanuts. Therefore, since the level of crime is precisely the tax revenue associated with t^*, an increase in police expenditure will increase crime if and only if the Laffer curve is negatively sloped at the equilibrium. The only difference between the condition established in Theorem 1 and the condition for the Laffer curve to be downward sloping, is that whereas an ad valorem tax rate is an exogenous variable determined by the government, the tax rate imposed by crime, t^*, is endogenously determined in equilibrium.

Theorem 1 suggests that by choosing an appropriate appropriation technology, an economy can be calibrated so that its equilibrium variables take any given values and where police has an adverse effect on crime. This is stated in the following proposition.

Proposition 1 Let T_0 be a given level of public police protection. Let $p^* > 0$, $Q^* > 0$, and $Y^* > 0$, be a price, quantity of peanuts, and a crime level. There exists an economy such that at its unique equilibrium the price, output and crime level are given by p^*, Q^*, and Y^*, respectively, and such that a small increase in police protection results in an increase in crime.

Proof : We will build an economy $\mathcal{E} = \langle(\phi, \overline{K}, \overline{L}), F, A, T_0\rangle$ with peanut price p^*, output Q^*, equilibrium crime level $Y^* > 0$, and such that if police protection is slightly increased the crime level will also increase. Theorem 1 establishes a condition for this to occur. Our task is then to build an economy that satisfies it.

If p^*, Q^*, and Y^* are the equilibrium price, output, and crime level of some economy with police protection given by T_0, using equation (7) we obtain that the equilibrium excise rate of theft is given by

$$A(Y^*, T_0) = \frac{Y^*}{p^*Q^* + Y^*}.$$

Let $0 < \alpha < A(Y^*, T_0)$. This α can be found since $Y^* > 0$. The production function of the economy is chosen to be $F(K, L) = K^\alpha L^{1-\alpha}$. Therefore, when the capital level is fixed at K, the corresponding short-run supply function is $Q(p) = K((1-\alpha)p)^{\frac{1-\alpha}{\alpha}}$. Note that the elasticity of supply is $\eta = \frac{1-\alpha}{\alpha}$. We now choose the capital endowment to be $\overline{K}$ such that $Q(p^*) = Q^*$. The choice of $\overline{L}$ is arbitrary although it can be chosen to be large enough so that the resulting equilibrium leisure is positive.

We now choose the utility function. Let $\hat{\varepsilon} < -1$ and $\hat{c} > 0$ be the unique solution of

$$\frac{(\varepsilon/2 - \eta)}{(1+\eta)\,\varepsilon/2} = A \tag{14}$$

$$\left(\frac{p^*}{c(1 - A(Y^*, T_0))}\right)^{\varepsilon} = Q^* \tag{15}$$

By the intermediate value theorem, this $\hat{\varepsilon}$ can be found because the left-hand side of (14), as a function of ε, is continuous in $(-\infty, 0)$, equals 1 when $\varepsilon = -2$, and

$$\lim_{\varepsilon \to -\infty} \frac{(\varepsilon/2 - \eta)}{(1+\eta)\,\varepsilon/2} = 1/(1+\eta) = \alpha < A(Y^*, T_0).$$

Note that since the left-hand side of (14) is increasing in ε, we have that

$$\frac{(\hat{\varepsilon} - \eta)}{(1+\eta)\,\hat{\varepsilon}} < A. \tag{16}$$

Once $\hat{\varepsilon}$ is found, $\hat{c}$ is obtained by solving equation (15).

We choose the consumers' utility function to be

$$\phi(x) = \hat{c}\,\frac{x^{1+1/\hat{\varepsilon}}}{1 + 1/\hat{\varepsilon}}.$$

Consequently, the corresponding demand function is $X(p) = (p/\hat{c})^{\hat{\varepsilon}}$, whose elasticity is constant and equal to $\hat{\varepsilon}$.

It remains to choose the appropriation technology. It will be given by

$$A(Y, T) = \frac{dY}{Y + p^*Q^*(\frac{T}{1+T} + e)}$$

where $e = \frac{1}{2(1+T_0)}$ and $d = \frac{\frac{p^*Q^*}{2} + p^*Q^*T_0 + T_0Y^* + Y^*}{p^*Q^* + p^*Q^*T_0 + T_0Y^* + Y^*}$. It is routine to check that $1 = g(Y^*, T_0)p^*Q^*$. Also, by the choice of the utility function (see equation (15)),

$X(\frac{p^*}{1-A(Y^*,T_0)}) = Q^*$. This means that the economy $\mathcal{E} = \langle(\phi, \overline{K}, \overline{L}), F, A, T_0\rangle$ has an equilibrium with price, quantity and crime level given by p^*, Q^*, and Y^*. Furthermore, since $d < 1$, $A(Y,T)$ is bounded away from one. Also, it can be checked that $g_1(Y,T) < 0$. Hence, the appropriation technology is regular and, by Observation 1, the equilibrium is unique. By construction, inequality (16) holds, which implies that inequality (8) also holds. By Theorem 1, we conclude that an increase in police protection increases the crime level. $\square$

One may argue that the perverse effect of police on crime identified in the above theorem results from a very peculiar appropriation technology. The next proposition, however, shows that this kind of perverse effect is compatible with any appropriation technology that is bounded away from one.

Proposition 2 Let T_0 be a given level of public police protection. Let A be an appropriation technology that is bounded away from one. Then there is an economy with appropriation technology A and police protection T_0 such that in equilibrium a small increase in police results in an increase in crime.

Proof : We will build an economy $\mathcal{E} = \langle(\phi, \overline{K}, \overline{L}), F, A, T_0\rangle$ with a positive equilibrium crime level $Y^* > 0$ and equilibrium price p^*, such that if police protection is slightly increased the crime level will also increase. Theorem 1 establishes a condition for this to occur. Our task is then to build an economy that satisfies it.

Let $\alpha \in (0,1)$ such that $A(Y,T_0) > \alpha$ for some Y, let $F(K,L) = K^\alpha L^{1-\alpha}$, and let $\overline{K} = 1$. As a result, the associated short-run aggregate supply function is given by $Q(p) = \big((1-\alpha)p\big)^{\frac{1-\alpha}{\alpha}}$ whose elasticity is $\eta = (1-\alpha)/\alpha$.

Since A is bounded away from one, we have that $\lim_{Y\to\infty} g(Y,T) = 0$. Therefore, for any Y, there is $\hat{Y} \geq Y$ such that $g_1(\hat{Y},T_0) < 0$. Consequently, we can choose $Y^* > 0$ such that both $A(Y^*,T_0) > \alpha$ and $g_1(Y^*,T_0) < 0$. This Y^* will be the equilibrium crime level in the economy we are seeking.

For any $b > 0$, consider the utility function given by $\phi_b(x) = b\,ln(x)$. The associated demand function is $X_b(p) = b/p$. The peanut market clearing condition $X_b(\frac{p}{1-A(Y^*,T_0)}) = Q(p)$ can be written as

$$\frac{b}{p}\,(1 - A(Y^*, T_0)) = Q(p)$$

It can be checked that this equation has a unique solution, which we denote by $p(b)$. Note that $\partial p/\partial b > 0$ and that $\lim_{b\to\infty} p(b) = \infty$.

Consider now the function

$$f(b) = g(Y^*, T_0)p(b)Q(p(b))$$

We have that f is increasing in b, $f(0) = 0$ and $\lim_{b\to\infty} f(b) = \infty$. By the intermediate value theorem, there is $\hat{b}$ such that $f(\hat{b}) = 1$. This means that $p^* = p(\hat{b})$ and Y^* satisfy

$$1 = g(Y^*, T_0)p^*Q(p^*) \tag{17}$$

$$X_{\hat{b}}(\frac{p^*}{1 - A(Y^*, T_0)}) = Q(p^*) \tag{18}$$

In other words, p^* and Y^* are an equilibrium price and a crime level of the economy $\mathcal{E}_{\hat{b}} = \left\langle(\phi_{\hat{b}}, \overline{K}, \overline{L}), F, A, T_0\right\rangle$, where $\overline{L}$ is arbitrary but can be chosen so that the equilibrium per capita leisure is positive.

We have built an auxiliary economy with an equilibrium price p^* and crime level Y^*. However, this equilibrium does not necessarily satisfy the condition of Theorem 1. We now build a collection of economies with the same equilibrium price and crime level and show that one of them satisfies this condition.

For any $\varepsilon < -1$, let $b(\varepsilon)$ be implicitly defined by

$$\left(\frac{p^*}{b(\varepsilon)}\right)^{\varepsilon} = Q(p^*)$$

namely,

$$b(\varepsilon) = Q(p^*)^{-\frac{1}{\varepsilon}}p^*$$

and define the following utility function: $\phi^{\varepsilon}(x) = b(\varepsilon)\frac{x^{1+1/\varepsilon}}{1+1/\varepsilon}$. Note that the corresponding demand function is $X^{\varepsilon}(p) = \left(\frac{p^*}{b(\varepsilon)}\right)^{\varepsilon}$. Let $\mathcal{E}^{\varepsilon} = \langle(\phi^{\varepsilon}, \overline{K}, \overline{L}), F, A, T_0\rangle$ be the economy that is obtained from $\mathcal{E}_{\hat{b}}$ by replacing the utility function $\phi_{\hat{b}}$ by ϕ^{ε}. It can be checked that p^* and Y^* are equilibrium values of both the economies $\mathcal{E}^{\varepsilon}$ and $\mathcal{E}_{\hat{b}}$. Indeed, if we substitute p^* for p and Y^* for Y in $\mathcal{E}^{\varepsilon}$'s equilibrium conditions

$$1 = g(Y, T_0) p Q(p) \tag{19}$$

$$\left(\frac{p^*}{(1 - A(Y, T_0))c(\varepsilon)}\right)^{\varepsilon} = Q(p^*) \tag{20}$$

and compare them with equations (17–18) we see that these conditions hold. See Figure 2.

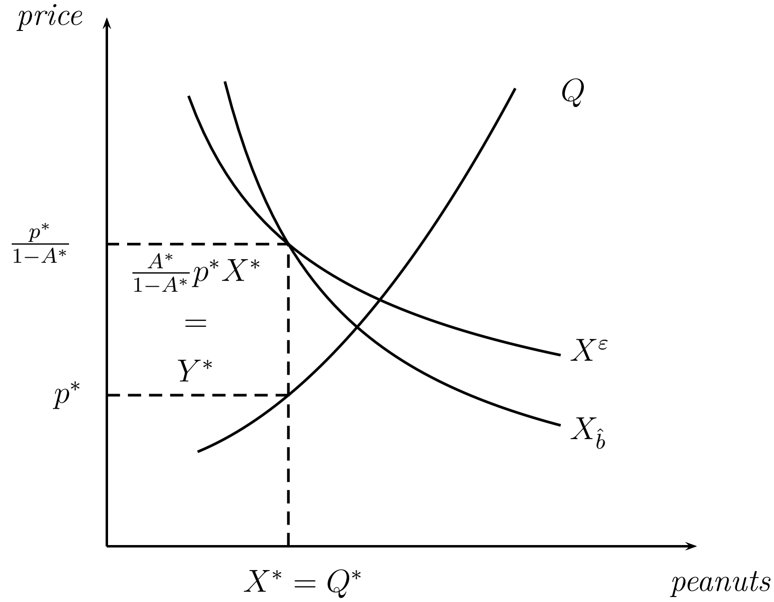

Figure 2: The pivoted demand function.

We now single out the economy $\mathcal{E}$ alluded to in the statement of the proposition. Since p^* does not depend on ε and since $\eta = \frac{1-\alpha}{\alpha}$,

$$\lim_{\varepsilon \to -\infty} \frac{(\varepsilon - \eta)}{(1 + \eta)\,\varepsilon} = \frac{1}{1 + \eta} = \alpha < A(Y^*, T_0).$$

Therefore, we can find $\tilde{\varepsilon}$ sufficiently negative so that

$$\frac{(\tilde{\varepsilon} - \eta)}{(1 + \eta)\,\tilde{\varepsilon}} < A(Y^*, T_0).$$

Given that $g_1(Y^*, T_0) < 0$, this shows that the economy $\mathcal{E}^{\tilde{\varepsilon}}$ satisfies Theorem's 1 conditions. Therefore, $Y'(T_0) > 0$ and $\mathcal{E}^{\tilde{\varepsilon}}$ is the economy $\mathcal{E}$ that we were looking for. $\square$

3.1 Optimal police protection

In this section we show that even when police protection is set at the optimal level, it may well be the case that more police induces more crime.

Let $\mathcal{E} = \left\langle (\phi, \overline{K}, \overline{L}), F, A, T \right\rangle$ be an economy with a regular appropriation technology, and let $Y(T)$ be the equilibrium crime level, which is assumed to be positive. Also let $p(T)$ be the equilibrium price. Denote by $X^*(T)$ and $Q^*(T)$ the equilibrium quantity of peanuts demanded and produced. Namely, $X^*(T) = X(p(T))$, and $Q^*(T) = Q(p(T))$. Given that preferences are quasilinear, we can evaluate the social desirability of allocations by the associated utility they generate. Thus, the social welfare corresponding to the equilibrium allocation when police protection is T, is given by

$$W(T) = \phi(X^*(T)) + \overline{L} - c(Q^*(T)) - Y(T) - T$$

where $c : \mathbb{R}_+ \to \mathbb{R}_+$ is the short-run cost function associated with the production function F. Namely, c is implicitly defined by $Q = F(\overline{K}, c(Q))$.[10] The optimal level of public police protection satisfies

$$\phi'(X^*(T))X^{*\prime}(T) = c'(Q^*(T))Q^{*\prime}(T) + Y'(T) + 1.$$

In other words, it equalizes the marginal cost of police with its marginal benefit. The marginal cost consists of three components: the production cost of the additional output induced by the additional police, the increase (which may be negative) in the crime level, and the additional expenditure on police. The marginal benefit is the increase in the consumers' utility due to the additional consumption of peanuts.

[10]Since the wage rate is 1, $c(Q)$ is the minimum amount of labor required to produce Q.

Since in equilibrium $X^*(T) = Q^*(T)$, $\phi'(X^*(T)) = p(T)/(1 - A(Y(T), T))$ and $c'(Q^*(T)) = p^*(T)$, we have that the optimal level of public police protection satisfies

$$\frac{A(Y(T), T)}{1 - A(Y(T), T)} p(T) Q^{*\prime}(T) = 1 + Y'(T). \tag{21}$$

By part 1 of Theorem 1, we have that the left-hand side of this equation is positive.[11] Therefore, it may well be the case that even at the optimal level of police protection we have that $Y'(T) > 0$. The following example illustrates such an instance.

Example 1 Consider the economy $\mathcal{E} = \left\langle (\phi, \overline{K}, \overline{L}), F, A, T \right\rangle$ where $\phi(x) = x(9 - x/2)$, $\overline{K} = 1$, $F(K, L) = \sqrt{KL}$, and $A(Y, T) = \frac{3}{4} \frac{Y}{1+Y+2\frac{T}{1+T}}$. With these data, the aggregate demand function is given by $X(p) = 9 - p$ and the short-run supply function is given by $Q(p) = p/2$. The unique equilibrium of this economy results from the solution of equations (5)–(6), which is

$$Y(T) = \frac{5 - 3T}{3T + 3} + \sqrt{\frac{57T + 25}{T + 1}} \qquad p(T) = 1 + \frac{1}{3}\sqrt{\frac{57T + 25}{T + 1}}.$$

The equilibrium crime rate $Y(T)$ is plotted in Figure 3. It can be seen that for $T < 11/21$, the crime rate increases with T. In particular, the maximum crime rate is not attained by reducing police funding to 0. Figure 3 also depicts the equilibrium social welfare as a function of police protection. It can be seen that it attains its maximum at $T^* = 0.419 < 11/21$. Therefore, in this economy, even at the optimal level of public police protection, an increase in police induces an increase in crime.

One would wonder why the social planner would not want to reduce police protection, even when at the optimum such a reduction would induce a decrease in crime. The answer can be seen from equation (21): a reduction in police protection

[11] If there were no feedback effect of crime, $Q^{*\prime}$ would be zero and at the optimal level of police we would have that $Y'(T) = -1$.

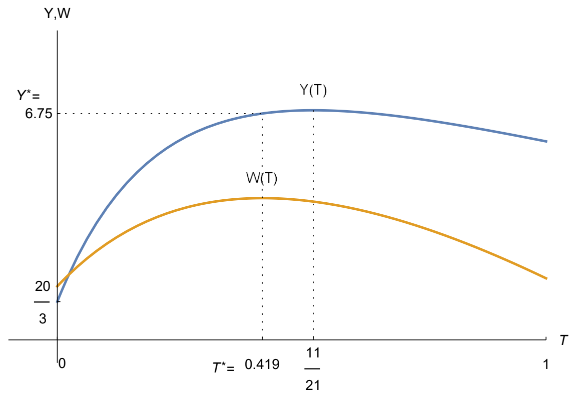

Figure 3: The equilibrium crime rate as a function of police protection and the optimal level of police protection.

decreases the equilibrium output with a corresponding reduction in consumer surplus, which turns out not to be compensated by the savings in police expenditure and the reduction in crime.

4 Concluding remarks

In this paper we showed that an ambiguous relationship between police and crime is consistent with a textbook general equilibrium model.

The economic theory of crime postulates that criminals are rational agents who respond to incentives. Thus, one of its main components is a supply of criminal activity that falls as the opportunity cost of crime rises. However, this supply function is not the only component of a general equilibrium theory. As a result, although *coeteris paribus* an exogenous increase in police shifts the supply of criminal offenses downwards, it may well be the case that the equilibrium level of crime goes up once all the general equilibrium effects are considered. Whether or not this is theoretically possible depends on the details of the whole model and not merely on the supply function. In fact, with the exception of Lasso de la Vega, Volij, and Weinschelbaum (2021) and Vásquez (2022), most of the existing theoretical models of crime predict that increases in police reduce crime. We now end the paper by highlighting the main insights of our paper and by discussing its relationship with the recent work of Vásquez.

a) *Theft as taxation.* In our model, theft imposes a tax on consumption goods. Indeed, the effective price paid by a consumer for a unit of consumption good is the sum of its market price and the value of the fraction stolen from him. The corresponding tax rate is shown to be negatively affected by police. Since in equilibrium, the resulting "tax revenue" equals the level of theft, an increase in police will induce more theft if and only if the Laffer curve of the economy at the equilibrium is downward sloping.

b) *Robustness.* We have further demonstrated that for the above-mentioned condition to hold it is not necessary to postulate any specific appropriation technology. On the contrary, for *any* appropriation technology, simple economies can be built in which the equilibrium effect of an increase in police spending results in higher levels of theft. Furthermore, this perverse effect can take place even at the socially optimal level.

c) *The measure of crime.* It is worth noting that the causal relationship between crime and police sought in the empirical literature may depend on the particular measure of crime that is used. In the context of property crime, one can think of three alternatives measures of theft. One is the total time devoted to it, another one is the value of the stolen goods, and the third one is the proportion of the output that is actually stolen. In our model, the first two measures coincide and differ from the third one. Our main result shows that while more police unambiguously induces less crime as measured by the third measure, it may well increase crime if it is measured by the first (and second) one.

d) *Comparison with Vásquez (2022).* Recently, Vásquez (2022) developed a game-theoretic model which shows that higher punishment may, under certain circumstances, induce a higher crime rate. Since his results resemble ours, we now briefly describe them and highlight the main differences.

While we model the agent's interaction as a production economy and apply the concept of competitive equilibrium, Vásquez models it as a strategic game and the concept is, consequently, that of a Nash equilibrium.

In Vásquez (2022) individuals are classified as either victims or potential thieves. In a Nash equilibrium, *i*) each victim chooses a level of vigilance that, given the mass of active thieves, minimizes the wealth stolen from him plus the cost of vigilance, and *ii*) a potential thief becomes active if, given the average vigilance level of the population, the wealth appropriated by him is at least as high as his cost of becoming a thief. The game admits a unique Nash equilibrium, which is summarized by the mass of active thieves and the average gross returns to theft. This equilibrium depends on the level of police activity (punishment, penalties, etc.), which is modeled as affecting the cost of becoming a thief. Since in this model, the total wealth is fixed, the level of crime can be measured in two ways. One is by the resources devoted to theft (mass of active thieves), and the other by the value (or proportion) of the stolen wealth. While, as mentioned before, in our model both measures coincide, in Vásquez (2022) they differ and may even move in opposite directions. In fact, the author shows that an increase in police unambiguously reduces the resources devoted to theft. However, since this reduction induces a drop in vigilance, the effect of an increase in police on the value of the stolen wealth is ambiguous. Moreover, under certain circumstances, the relationship between these two variables has an inverted U shape, which the author calls the "criminal Laffer curve". In contrast, in our model police has an ambiguous effect on theft, both measured as the value of stolen goods and as the resources devoted to theft.

It is worth mentioning that the mechanisms that lead to the perverse effect of police on crime are different in the two models. In both of them, *coeteris paribus*, more police reduce the incentives to engage in theft. However, while in Vásquez's model, public police crowds out vigilance which boosts the returns to theft, in our model, more police induces economic prosperity which in turn increases the returns to theft.

A Appendix

Proof of Observation 1 By our assumptions on ϕ and F, for any fixed Y, equation (6) has a unique solution, which we denote by $p(Y)$. It can be checked that $p(Y)$ is non-increasing in Y and, consequently, $Q(p(Y))$ is non-increasing in Y as well. Therefore, $\mathcal{E}$ has an equilibrium if

$$1 - A(Y,T) \geq a(Y,T)p(Y)Q(p(Y)) \quad \text{with equality if } Y > 0.$$

Since A is bounded away from one, this is equivalent to

$$1 \geq \frac{a(Y,T)}{1 - A(Y,T)} p(Y)Q(p(Y)) \quad \text{with equality if } Y > 0. \tag{22}$$

If $1 \geq \frac{a(0,T)}{1-A(0,T)}p(0)Q(p(0))$, then $Y^* = 0$ solves (22). If, on the other hand, $1 < \frac{a(0,T)}{1-A(0,T)}p(0)Q(p(0))$, then, given that $p(Y)Q(p(Y))$ is non-increasing, that A is bounded away from one, and that $a(Y,T)$ goes to 0 as Y goes to ∞, we have that $\frac{a(Y,T)}{1-A(Y,T)}p(Y)Q(p(Y)) \to 0$ as Y goes to ∞. By the intermediate value theorem, there is Y^* such that $1 = \frac{a(Y^*,T)}{1-A(Y^*,T)}p(Y^*)Q(p(Y^*))$ and an equilibrium exists. If $\frac{a(Y,T)}{1-A(Y,T)}$ is non-increasing, this Y^* is unique and so is the equilibrium. $\square$

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