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Burglary and income inequality

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Abstract

In a model where risk-neutral agents have differing (legal) incomes which may be supplemented by burglary, we study the effects of income distribution on the level of burglary. Assuming that a detected burglar is incarcerated for a fixed term, and assuming that burglars choose target houses using the signal of house quality, we show how increases in income inequality may increase the level of crime. In particular, increases in 'relative differential' inequality, unambiguously increase burglary crime. Corollaries are that a more regressive income tax increases the level of crime, and that richer neighborhoods may have lower crime rates. © 1998 Elsevier Science S.A.

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1. Introduction

The objective is to present an economic model of a particular category of property crime (burglary). The model determines endogenously the set of offenders, the set of victims and the number of offenses, and we investigate the relationship between the resulting level of crime and the distribution of income. We show that the number of burglaries increases as the income distribution becomes more unequal, in ways to be made precise. The paper thus provides a theoretical explanation for a relationship between income inequality and property

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crime which has general empirical support (Freeman (1996), p. 33) and the references therein).

The mechanism whereby income inequality influences burglary in the paper is as follows. Suppose burglary is punished by incarceration, and suppose all individuals understand the technology of crime commission (how to 'break and enter', etc). Since incarceration entails loss of income for a period, individuals with low earning potential have (ceteris paribus) a greater incentive to take the risk of engaging in burglary than richer individuals.[1] Moreover, this incentive increases if the income distribution changes so that low incomes become lower. On the other hand, a burglar has to act typically on imperfect signals about the potential proceeds from burgling a particular property, and there is some empirical evidence that house quality may well be just such a signal.[2] If, as is natural to expect, richer individuals live in the better houses, it is the rich end of the income distribution who will be the potential burglary victims. Moreover, if the rich get richer the attractiveness of burglary increases. Thus, if income inequality increases so that low incomes become lower and higher incomes become higher, then the level of crime is driven up from two sources: the alternative to crime is less attractive for criminals and the potential proceeds from crime are greater. In what follows we present a formal model which allows precise investigation of this mechanism.[3]

The model has a continuum of risk-neutral agents who earn differing legal post-tax incomes. Individuals may also engage in (at most one in our time frame) burglary, a risky activity which leads to a fixed (exogenous) prison sentence with some (exogenous) probability; additionally the burglary yields some (exogenous) fraction of the residual income of the individual who resides at the house. The implicit geographic focus of the model is a neighborhood[4] where there are given quantities of two qualities of houses, the higher quality costing (an endogenous amount) more than the lower quality; residual income is post-tax income less housing costs. For simplicity, we assume that all individuals are equally 'amoral',

[1]Our model will be a static model, so the impact of incarceration is purely as a deterrent. In a dynamic model, incapacitation effects (those in prison cannot commit crime) would also emerge, although some recent U.S. empirical evidence suggests that the deterrence effect is the more important (Levitt, 1995).

[2]See discussion in Hope (1984), especially p. 48–52; see also Osborn and Tseloni (1995) for recent UK empirical evidence on the relative vulnerability to burglary of semi-detached and higher quality houses.

[3]Whilst similar mechanisms may be at work for some other categories of property crime, we neither claim nor expect universality. Indeed some categories of property crime clearly violate our assumption that individuals at all income levels have the capacity to commit (e.g. complicated financial fraud), whilst others are punished by means-tested fines. In the former case one might also expect the value of crime to be a more natural focus than our level of crime.

[4]Burglars tend not to travel too far to commit crime (not more than a few miles typically), so the appropriate geographic manifestation of neighborhood, is relatively small: see Bottoms (1994), for further discussion.

basing the burglary decision solely on expected income maximization. We show that, for certain parameter values, there is a unique equilibrium in which all burglars target the higher quality houses which will belong to the richest section of the community, and that the criminals will be the poorest section of the community, where 'poorest' and 'richest' are in terms of legal post-tax earnings, thus establishing the potential link between income inequality and crime of the last paragraph. We show how increases in Lorenz inequality (plus some additional conditions), or, most powerfully, increases in 'relative differential' inequality (associated with Lorenz worsening on any subinterval of incomes—see e.g. Moyes, 1994) both lead to increases in the level of crime. The latter result is particularly useful, and allows us to go on to see how increases in income tax progressivity may lead to lower levels of crime, and to investigate why richer neighborhoods may have lower crime rates.

The economics of crime literature originated with the seminal contribution of Becker (1968). The subsequent literature has investigated individual decisions in relation to crime (e.g., Ehrlich, 1973; Block and Heineke, 1975) and various aspects of the interaction between criminals, victims and police. In the latter literature there are studies whose primary focus is social welfare issues such as optimal punishment (e.g., Benoit and Osborne, 1992; Furlong, 1987; Polinsky and Shavell, 1979, 1984; Shavell, 1991), others which focus on dynamic issues (Davis, 1988; Neher, 1978) and a third group (where our paper lies most naturally) which attempt to understand the aggregate level of crime by studying aggregate comparative statics (e.g. Balken and McDonald, 1981; Deutsch et al., 1987). In this literature others have suggested theoretical links between income inequality and crime, most notably Ehrlich (1973) in an analysis of property crime focusing on offender behavior, and Benoit and Osborne (1992) who study individual and collective choice of punishment level (and hence the level of crime) and how certain features of the income distribution might affect such choices. Our innovation is that we provide a microfoundation for offender behavior, victim behavior and their interaction, producing a level of crime which is influenced by changes in income inequality according to the standard Lorenz criterion and its relative differential extension. Our modelling strategy was inspired by that of Furlong (1987), although our focus on 'positive' analysis of burglary (as opposed to 'normative' consequences of street crime) have led to major differences ultimately; in particular heterogeneity of individuals is critical for our model (there is homogeneity in Furlong, 1987) and we make simplifying assumptions elsewhere (e.g., we do not model the offender–police interaction in detail) so as to handle this complication. The recent paper by Doyle (1994) is perhaps closest in spirit to ours with a set of low income criminals whose crimes are driven by drug consumption, rather than our inequality.

Section 2 sets out the model, Section 3 presents the main inequality results, Section 4 looks at income tax progression, Section 5 studies the level of crime in richer neighborhoods, and Section 6 concludes.

2. The model

We consider a neighborhood inhabited by a continuum of risk-neutral individuals, whose (exogenous) legal post-tax incomes are distributed over the interval $[\underline{y}, \bar{y}]$, $\underline{y} < \bar{y}$; the income distribution function $F:[\underline{y}, \bar{y}] \to [0, 1]$ is strictly increasing and twice continuously differentiable. There is a given housing stock in the neighborhood, a fraction $v(<1/2)$ of which is of high quality (HQ), the rest being low quality (LQ). Individuals are mapped one-to-one to houses in which they reside, so that a fraction v will live in HQ. We assume that the cost of LQ is exogenous and, for simplicity, is equal to zero;[5] the price differential between HQ and LQ, or equivalently the HQ price, is the endogenous amount r. Every individual shares the same VNM utility function (of his income and the type of house he lives in). Specifically, defining residual income as post-tax income less housing cost, any individual with residual income z has a utility level equal to z if he lives in LQ, and μz if he lives in HQ, where $\mu > 1$. The price r adjusts to clear the housing market, so that the allocation of the fraction v of the population to HQ is the result of individually optimal decision. $H \subset [0, 1]$ denotes the (endogenous) set of individuals who live in HQ.

Individuals can choose to engage in burglary of a house, additional to the activity which produces the legal post-tax income. The timeframe of our model is such that each individual will engage in at most one burglary, and that each house can be burgled at most once.[6] A burglary is detected by police with the (exogenous) probability p. If detected, the burglar receives a standard prison sentence which precludes the individual from enjoying any income—with probability p the income of a burglar is zero. If not detected, a burglar acquires a given proportion β of the residual income of the individual residing at the burgled house. We think of β as typically being relatively small. The type of a house (HQ or LQ) is perfectly observable, but the income of the resident is not known to a burglar prior to burglary, only the distribution of (residual) income across HQ and LQ houses. Thus house type becomes a signal to prospective burglars, who have to decide whether to burgle a HQ house, a LQ house, to randomize this choice, or to burgle neither. From these decisions there emerges an (endogenous) set of potential victims $V \subset [0, 1]$. The (endogenous) set of burglars (criminals) is denoted $C \subset [0, 1]$, and there is a random matching process between C and V.

Generally, an equilibrium in the model is C, H and $V \subset [0,1]$ and a price r which are the result of mutually consistent and individually optimal decisions regarding

[5] However, all our formal results hold if the LQ price is some positive constant, except the result on progressive taxation in Section 4, where a sufficiently positive LQ price can create some ambiguity in the result.

[6] It would be of interest to develop the model into a dynamic context, thus relaxing these assumptions. In particular, the model would then allow multiple victimization, whose empirical importance is now well established in the criminology literature: see Trickett et al. (1992) and Osborn et al. (1996) for recent UK empirical work and earlier references.

housing and burglary. We restrict attention to the study of equilibria in which the level of crime (i.e., the number of burglars under the assumption that burglars commit just one burglary) satisfies the following:

$$\lambda(V) > \lambda(C) = c > 0\ ,$$

where $\lambda(S)$ is the measure of set S. That is, there are some criminals, but fewer criminals than potential victims. Given this, we assume that the criminal/victim matching maps the set C one-to-one onto a proper subset of V so that no one is mapped to themselves, and so that all mappings are equally likely, leading to a victimization probability of $q = c/\lambda(V) \in (0,\ 1)$ for each member of V. We show that for certain sets of parameters, there is a unique equilibrium, and in this equilibrium the potential victims are the HQ residents, i.e., $V = H$, so $\lambda(V) = \lambda(H) = v$.

To define such an equilibrium precisely, let $m(V) = 1/(\lambda(V)) \int_{F^{-1}(V)} y\ \mathrm{d}F$ be the expected post-tax income of the set of individuals $V \subset [0,\ 1]$. Denoting by $\overline{V}$ the complement of V, prospective burglars will prefer to target $V(=H)$ rather than the alternatives if $m(V) - r > m(\overline{V})$, which will become an equilibrium condition. In general, individual housing/burglary decisions divide the population into four classes;

Class 1. For individuals in $V = H$ and not in C (i.e., $V \cap \overline{C}$) with income y, expected utility is $U_1 = \mu[(1-q)(y-r) + q(1-\beta)(y-r)] = \mu(1-q\beta)(y-r)$.

Class 2. For $\overline{V} \cap \overline{C}$, $U_2 = y$.

Class 3. For $\overline{V} \cap C$, $U_3 = (1-p)[y + \beta(m(V) - r)]$.

Class 4. For $V \cap C$, $U_4 = \mu(1-p)[(1-q\beta)(y-r) + \beta(m(V) - r)]$.

The specification of U_4 presumes that stolen property will not be stolen from the burglar, creating a larger value for U_4 than the alternatives. However the assumption is innocuous as we shall impose assumptions under which class 4 is empty in equilibrium. Notice also that expected income dictates the burglary decision, without the interference of any moral or other considerations; it would be a trivial matter, however, to admit a subset of individuals randomly distributed over the income distribution whose moral or other considerations preclude their engagement in crime. The equilibrium of interest is:

Definition 1. An equilibrium is a *set of potential victims* $V(=H) \subset [0,\ 1]$, a *set of criminal*s $C \subset [0,\ 1]$, and *a price r such that the victimization probability* $q = \lambda(C)/\lambda(V) \in (0,\ 1)$ *and*;

(E1) $U_1 \geq \max\{U_2, U_3, U_4\}$ for y where $F(y) \in V \cap \bar{C}$,

(E2) $U_2 \geq \max\{U_1, U_3, U_4\}$ for y where $F(y) \in \bar{V} \cap \bar{C}$,

(E3) $U_3 \geq \max\{U_1, U_2, U_4\}$ for y where $F(y) \in \bar{V} \cap C$,

(E4) $U_4 \geq \max\{U_1, U_2, U_3\}$ for y where $F(y) \in V \cap C$,

(E5) $m(V) - r > m(\bar{\mathrm{V}})$,

(E6) $\lambda(V) = v$,

Here (E1)–(E5) ensure optimality of individual housing and burglary decisions, and (E6) ensures that the housing market 'clears'. We assume throughout that both $\mu > 1$ and $\beta \in (0, 1)$ are not 'too big', as well as the earlier assumption that $v < 1/2$. To be precise, denote $\beta(1-p)/p$ as σ and define $\delta = \min\{y/x | F(y) = F(x) + 1 - 2v,\ x \geq \underline{y},\ y \leq \bar{y}\}$ (i.e., δ is the minimum ratio of highest to lowest income in a set of individuals of measure $(1-2v)$. Since $v < 1/2$, $1 - 2v > 0$, and $\delta > 1$. We impose the following additional assumptions throughout.

Assumption 1. $\mu < \delta$ and $\beta < \gamma$ where $\gamma = (\sigma(\delta - 1)(\mu - 1))/((\mu - 1) + \mu\sigma(\delta - 1))$.

Under Assumption 1, a necessary condition for equilibrium is a class structure in which the lowest income individuals are criminals in lower quality housing, middle incomes lead to noncriminality, still in LQ, and the highest incomes are noncriminals living in HQ and thus the potential victims (class 4 is empty in equilibrium.). Appendix A proves the following:

Lemma 1. *Under Assumption 1, necessary conditions for equilibrium are that the set of criminals coincides with class 3 and is* $C = [0, c]$ *for some* $c = \lambda(C) < v$ *with marginal criminal income* $y^c = F^{-1}(c)$; *the set of victims* $V = H = [1 - v, 1]$ *coincides with class 1 with marginal victim income* $y^v = F^{-1}(1 - v)$; *remaining individuals in* $[c, 1 - v]$ *are in class 2. In addition, if r is the equilibrium house price differential, then*

$$y^c = \sigma(m(V) - r), \tag{EA}$$

$$F(y^c) = \frac{v}{\beta}\left[1 - \frac{y^v}{\mu(y^v - r)}\right], \tag{EB}$$

describe, respectively, the marginal criminal's indifference between class 3 and 2, and the marginal victim's indifference between class 1 and 2.

Lemma 1's necessary conditions tell us that equilibrium values of y^c and r must satisfy (EA) and (EB). This figure shows one configuration of the (downward-sloping) graphs of these two relations, and will motivate the subsequent sufficient conditions.

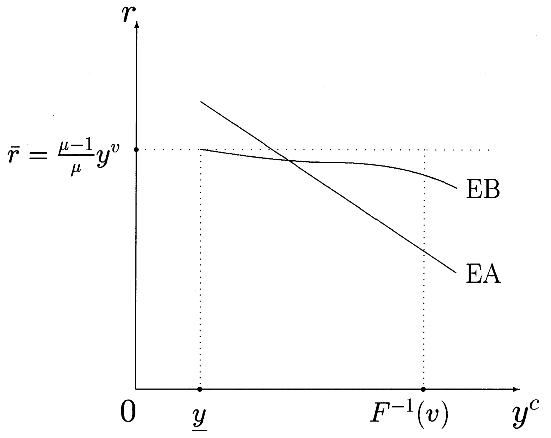

Fig. 1.

Notice that for small β, the graph of (EB) is close to (just below) the horizontal line $r=\bar{r}=\dfrac{(\mu-1)y^v}{\mu}$; this house price differential $\bar{r}$ is the value which would emerge in the absence of crime (e.g., $\beta=0$), and so it is natural that the equilibrium r will be below this, but close to it, when β is small. Imposing Assumption 2(b) (below) on σ so that (EA) intersects the line $r=\bar{r}$ at some $y^c \in (\underline{y}, F^{-1}(v))$ ensures a unique (EA)/(EB) intersection for small enough β. Since $r<\bar{r}$, condition (E5) will be satisfied if $m(V)-m(\bar{V})>\bar{r}$ (where $V=[1-v, 1]$), which is Assumption 2(a).

Assumption 2.

$$(a)\ \mu < \frac{F^{-1}(1-v)}{\max\{0, F^{-1}(1-v)-(m(V)-m(\bar{V}))\}}$$

$$(b)\ \frac{F^{-1}(v)}{m(V)-\dfrac{\mu-1}{\mu}F^{-1}(1-v)} > \sigma > \frac{\underline{y}}{m(V)-\dfrac{\mu-1}{\mu}F^{-1}(1-v)}$$

It is now straightforward to 'reverse' the logic of Lemma 1 and show that Assumptions 1 and 2 and 'β being small' ensure a unique equilibrium (with

$V=H$). Moreover these assumptions preclude other equilibria where $V=H$ are not the burglary targets. We have the following,[7]

Lemma 2. *Under Assumptions 1 and 2, if β is sufficiently small*

(*a*) *There exists a unique equilibrium* (*with $V=H$*);

(*b*) *There is no other type of equilibrium* (*i.e., there is no equilibrium with $V\neq H$*).

The parameter restrictions which generate existence and uniqueness can be interpreted as follows. First, the fact that β is 'small' ensures that crime has only a 'small' effect on the house price differential. Secondly, that $\sigma=\beta(1-p)/(p)$ lies between positive upper and lower bounds entails that p (like β) is 'small' and generates a positive level of crime—the 'small' proceeds from burglary (β) are compensated from the burglar's perspective by the 'small' probability of detection (p). Thirdly, the assumption that μ is not too big ensures that the cost of HQ housing is not so great as to leave the occupants with sufficiently low disposable income that LQ houses become a more attractive target. In all three cases we feel that the assumptions are at the empirically more plausible end of the spectrum.

3. Income inequality and the level of crime

To study the effects of a change of income distribution on the level of crime, we suppose that the original distribution F defined on $[\underline{y}, \bar{y}]$ gives way to a new distribution G defined on $[\underline{x}, \bar{x}]$. Where necessary, we subscript variables by F or G to differentiate the two cases. We assume that the income distribution is the only change and that F and G are sufficiently similar so that Lemmas 1 and 2 apply to both. To save further repetitions, we assume:

Assumption 3. The income distributions F and G and the parameter values are such that Assumptions 1 and 2 are satisfied; also β is sufficiently small that lemmas 1 and 2 apply.

From Lemma 2, Eqs. (EA) and (EB) determine the equilibrium level of crime (and house price differential). The income distribution directly influences these equations from three directions: first, via $m(V)$, which is the average income of potential victims; second, via y^v, which is the income of the poorest (marginal) potential victim; and third, via y^c, which is the income of the richest (marginal) criminal. Intuition suggests the following argument. Suppose the income dis-

[7] A complete proof can be found in an earlier version of our paper (Chiu and Madden, 1996), available to readers upon request.

tribution changes in the following ways; (a) the average income of the top $100v\%$ of the population increases (i.e., $m(V)$ increases), (b) the income of the marginal victim under the original distribution goes down (i.e., y^v decreases), and (c) the income of the marginal criminal under the original distribution goes down (i.e., y^c decreases). The effect of (b) will be to lower the house price differential r, so that the effect of both (a) and (b) will be in the same direction, increasing the attractiveness of a burglary. Moreover, this is reinforced by (c) in that, after the income distribution change, the (former) marginal criminal has less legal income and so more incentive to burgle.

Theorem 1. *Suppose Assumption 3 holds, and suppose that the income distribution change from F to G is such that*

$$(a)\ \frac{1}{1-v}\int_{G^{-1}(1-v)}^{\bar{x}} x\,\mathrm{d}G > \frac{1}{1-v}\int_{F^{-1}(1-v)}^{\bar{y}} y\,\mathrm{d}F$$

(b) $G^{-1}(1-v)<F^{-1}(1-v)$

(c) $G^{-1}(c_F)<F^{-1}(c_F)$ *where* c_F *is the equilibrium crime level under F.*

Then the equilibrium level of crime increases (*i.e.*, $c_G>c_F$).

Proof. The effect of the change on (EA) is through (a) and is such that the (EA) line in Fig. 1 shifts to the right. At the original equilibrium house price differential r_F, the effect on (EB) is through (b) and (c). The change in (b) causes y^v to fall and so the right-hand side of (EB) falls. Thus $G(x^c)<F(y^c)$ at r_F and so $x^c<y^c$ at r_F from (c). Thus (EB) shifts to the left, at least near r_F. The new (EA)/(EB) intersection thus occurs at a higher level of the marginal criminal's income, and so (from (c)) the crime level is also higher. □

The conditions of Theorem 1 can be partially related to the Lorenz curve comparison for F and G. The Lorenz curve for income distribution F is the graph of the following function $L_F:[0, 1]\rightarrow[0, 1]$;

$$L_F(i)=\frac{\int_{\underline{y}}^{F^{-1}(i)} y\,\mathrm{d}F}{\int_{\underline{y}}^{\bar{y}} y\,\mathrm{d}F}$$

With similar definition of L_G, we have the following well-known criterion for comparing income distributions (see Lambert, 1989) for further discussion):

Definition 2. The income distribution G exhibits greater Lorenz inequality than F iff $L_F(i) > L_G(i)$, $i \in (0, 1)$.

If F and G have the same mean and if G exhibits a greater Lorenz inequality than F, then notice, in particular, that condition (a) of Theorem 1 follows.

Theorem 2. *Suppose Assumption 3 holds. Suppose that income distribution G exhibits a greater Lorenz inequality than F with the same mean, and that only the top 100θ% of individuals are better off under G than under F, where θ<v. Then the level of crime is higher under G than under F.*

Proof. The Lorenz assumption ensures condition (a) of Theorem 1. Condition (b) and (c) of Theorem 1 are also satisfied since at least the poorest $100(1-v)\%$ of individuals are worse off under G. Thus the conclusion of Theorem 1 continues to hold. □

Theorem 1 and 2 both require that the change from F to G makes both the marginal potential victim and the marginal criminal worse off (conditions (b) and (c), respectively) and the average potential victim better off (condition (a)). However intuition suggests that the same conclusion may emerge if the strength of these three changes relative to each other (rather than their absolute direction) is 'appropriate'. In particular, one might expect that if the change in the average income of the potential victims (i.e., $m_G(V) - m_F(V)$) is larger than the corresponding change in the marginal potential victim's income, which in turn is larger than the corresponding change in the marginal criminal's income, then the overall effect will still be to make crime more attractive to the marginal criminal, and thus produce an increase in crime. It is possible to give a neat sufficient condition to this effect, using the following alternative to the Lorenz criterion.

Definition 3. The income distribution G exhibits greater relative differential inequality than F if and only if $G^{-1}(i)/F^{-1}(i) > G^{-1}(j)/F^{-1}(j)$ for all $i, j \in [0, 1]$ where $i > j$.

For instance, with $i = 0.9$ and $j = 0.1$, this requires that the 'decile ratio' for $G(=G^{-1}(0.9)/G^{-1}(0.1))$ exceed that for F. For finite populations the concept has been studied extensively by Moyes (1994), following earlier work by Preston (1990) and Thon (1987).[8] The insights which emerge include the facts that (i) greater relative differential inequality implies greater Lorenz inequality and (ii) greater relative differential inequality is equivalent to greater Lorenz inequality for every corresponding subgroup of individuals where the correspondence is based on

[8] Focus on inverse income distribution functions is also central to Atkinson and Bourguignon (1989) who draw analogues with the dual theory of risky choice (Yaari, 1987).

an individual's rank in the income distribution, insights which remain in our 'continuum' context.[9]

We now have the following result.

Theorem 3. *Suppose Assumption 3 holds, and suppose that income distribution G exhibits a greater relative differential inequality than F. Then the level of crime is higher under G than under F.*

Proof. From (EA) for F and for G, after rearranging, $c_G > c_F$ if and only if

$$\frac{m_G - r_G}{m_F - r_F} > \frac{G^{-1}(c_F)}{F^{-1}(c_F)}, \tag{1}$$

where $m_G = (1)/(1-v) \int_{G^{-1}(1-v)}^{\bar{x}} x \, \mathrm{d}G$ and similarly for m_F. From the relative differential assumption,

$$\frac{G^{-1}(c_F)}{F^{-1}(c_F)} < \frac{G^{-1}(1-v)}{F^{-1}(1-v)},$$

so that (1) will be true provided

$$\frac{m_G - r_G}{m_F - r_F} > \frac{G^{-1}(1-v)}{F^{-1}(1-v)}. \tag{2}$$

Substituting the formulae for r_F, r_G which follow from rearranging (EB) for F and for G, (2) is equivalent to

$$F^{-1}(1-v)\left\{ m_G - G^{-1}(1-v)\left[1 - \frac{1}{\mu\left(1 - \frac{\beta}{v} c_G\right)} \right] \right\}$$
$$> G^{-1}(1-v)\left\{ m_F - F^{-1}(1-v)\left[1 - \frac{1}{\mu\left(1 - \frac{\beta}{v} c_F\right)} \right] \right\},$$

which on further rearrangement becomes

$$\frac{\mu m_G}{G^{-1}(1-v)} - \frac{\mu m_F}{F^{-1}(1-v)} > \frac{1}{1 - \frac{\beta}{v} c_F} - \frac{1}{1 - \frac{\beta}{v} c_G}. \tag{3}$$

Since $0 < c_F$, $c_G < v$, the right-hand side of (3) has an upper bound of $1/(1-\beta) -$

[9]Our earlier discussion paper (Chiu and Madden (1996), available on request from the authors) contains proofs of this assertion and also the following Lorenz curve characterization of the relative differential concept: G exhibits a greater relative differential inequality than F if and only if the ratio of the slope of the Lorenz curves, $L'_G(i)/L'_F(i)$ is increasing with i on [0, 1].

$1=\beta/(1-\beta)$. On the other hand, letting Z denote the left-hand side of (3), we have

$$Z=\frac{\mu}{v}\left(\frac{\int_{G^{-1}(1-v)}^{\bar{x}} x\,\mathrm{d}G}{G^{-1}(1-v)}-\frac{\int_{F^{-1}(1-v)}^{\bar{y}} y\,\mathrm{d}F}{F^{-1}(1-v)}\right)$$

$$=\frac{\mu}{v}\left(\frac{\int_{1-v}^{1} G^{-1}(i)\,\mathrm{d}i}{G^{-1}(1-v)}-\frac{\int_{1-v}^{1} F^{-1}(i)\,\mathrm{d}i}{F^{-1}(1-v)}\right),$$

$$=\frac{\mu}{vG^{-1}(1-v)}\int_{1-v}^{1}\left[G^{-1}(i)-\frac{G^{-1}(1-v)}{F^{-1}(1-v)}F^{-1}(i)\right]\mathrm{d}i.$$

Defining

$$\Gamma(i)\equiv\left[G^{-1}(i)-\frac{G^{-1}(1-v)}{F^{-1}(1-v)}F^{-1}(i)\right]=F^{-1}(i)\left[\frac{G^{-1}(i)}{F^{-1}(i)}-\frac{G^{-1}(1-v)}{F^{-1}(1-v)}\right].$$

$\Gamma(1-v)=0$ and $\Gamma(i)>0$ for $i>1-v$ by the relative differential assumption. Thus $Z>0$ independently of β and (3) follows if $Z>\beta/(1-\beta)$ or $\beta<Z/(1+Z)$. Thus (3) will hold for β sufficiently small, as was assumed in Assumption 3. □

Theorem 3 entails also that the level of crime is lower under G than under F if $G^{-1}(i)/F^{-1}(i)$ is everywhere decreasing, and that the level of crime is the same in G and F if $G^{-1}(i)/F^{-1}(i)$ is everywhere constant. Thus given that G and F can be ranked by the relative differential criterion, an increase in income inequality is a necessary and sufficient condition for an increase in the level of crime. The final two sections develop further insights from Theorem 3 in two directions.

4. Progressive taxation and the level of crime

Consider the decomposition of our post-tax income into a pre-tax income and an income tax, in order to investigate changes in tax progressivity. Specifically suppose that $F:[\underline{Y},\bar{Y}]\rightarrow[0,1]$ is the distribution function for pre-tax income Y. Suppose $t(Y)$ and $\hat{t}(Y)$, defined for $Y\in[\underline{Y},\bar{Y}]$, are two income tax schedules which define the income tax payable on income Y with $t(Y)$, $\hat{t}(Y)\leq Y$ and $0\leq t'(Y)$, $\hat{t}'(Y)\leq 1$, so that the tax schedules induce no 'reranking'. Let $G(Y-t(Y))$ and $\hat{G}(Y-\hat{t}(Y))$ be the distribution functions for post-tax income induced by t and $\hat{t}$ respectively. Then $G(Y-t(Y))=F(Y)$ and $\hat{G}(Y-\hat{t}(Y))=F(Y)$, so that $G^{-1}(i)/\hat{G}^{-1}(i)=[F^{-1}(i)-t(F^{-1}(i))]/[F^{-1}(i)-\hat{t}(F^{-1}(i))]$. Hence $G^{-1}(i)/\hat{G}^{-1}(i)$ increases with i if and only if

$$\frac{Y - t(Y)}{Y - \hat{t}(Y)} \text{ increases with } Y \text{ for all } Y \in [\underline{Y}, \bar{Y}].$$

But this is the usual definition of $\hat{t}$ being a more progressive tax than t, so $\hat{t}$ is more progressive than t if and only if t induces a post-tax distribution of income which exhibits a greater relative differential inequality than that induced by $\hat{t}$. This type of relation is well-known in the income distribution literature (see for example, Lambert (1989); Moyes (1994)). It allows us to assert, from Theorem 3;

Corollary 1 to Theorem 3. *Increases in income tax progressivity reduce the crime rate.*

In particular, a poll tax ($t(Y)=\bar{T}$ for all Y) would induce a higher crime rate than a proportional tax ($t(Y)=\tau Y$ for all Y), which would in turn induce a higher crime rate than a progressive tax ($t(Y)/Y$ increases with Y for all Y).

5. Richer neighborhoods and the level of crime

It is a common belief that richer neighborhoods may endure a lower level of crime than poorer neighborhoods; our model allows this possibility. For instance, if incomes in neighborhood G are higher by an equal amount Δ than the corresponding income in neighborhood F, so that $G^{-1}(i)=F^{-1}(i)+\Delta$, then $G^{-1}(i)/F^{-1}(i)$ decreases with i and (under Assumption 3) the level of crime is lower in the richer neighborhood G than in F; richer neighborhoods, in this absolute differential sense, will have lower crime rates. In general, if G is a richer neighborhood than F in that $G^{-1}(i)>F^{-1}(i)$ for all $i\in[0, 1]$, then the richer neighborhood will have the lower crime rate if $G^{-1}(i)/F^{-1}(i)$ is decreasing with i, i.e., if it has a lower relative differential income inequality. We may conclude:

Corollary 2 to Theorem 3. *Richer neighborhoods may have lower crime rates than poorer neighborhoods because they may have a lower relative differential income inequality.*

On the other hand, one might also expect that richer neighborhoods may have lower burglary rates because of a greater preponderance of security measures in the *HQ* housing, a feature not modelled so far. To address this, consider a neighborhood F in which there is an equilibrium $\hat{y}^c$, $\hat{r}$ with $\hat{q}=F(\hat{y}^c)/v$, characterized by the (EA)/(EB) intersection in Fig. 1. Now suppose that an effective defence technology against burglary (e.g. an alarm, security fence, etc.) becomes available to each household at a fixed cost a. To save on notation, suppose the technology is completely effective if adopted, in that criminals will never attempt to burgle a protected property (e.g. $\beta=0$ or $p=1$ for such properties). From the initial equilibrium only class 1 households would consider adoption, and such a household with income y would not wish to adopt if

$$\mu(1-\hat{q}\beta)(y-\hat{r}) \geq \mu(y-\hat{r}-a)\,,\ \text{i.e.,}\ a \geq \hat{q}\beta(y-\hat{r}).$$

Thus if $a \geq \bar{a} \equiv \hat{q}\beta(\bar{y}-\hat{r})$, the defence technology is too expensive for any household to adopt, and the initial equilibrium remains. A complete global analysis of the case where $a<\bar{a}$ is somewhat intractable. Instead, we offer one 'local' observation which supports the theme of this section. Suppose $\bar{a}=a$ in neighborhood F so that no household adopts (just), and compare this with another neighborhood G in which all incomes are scaled up by a small amount, everything else (including a) the same; that is, assume $G^{-1}(i)=\rho F^{-1}(i)$ for some ρ just in excess of unity. If the defence technology were not available, both neighborhoods would have the same level of crime, so that the Corollary 2 effect is absent. However, with the availability of the defence technology one expects that the richest households in G would start to adopt, increasing the victimization probability for nonadopting HQ households, causing further adoption. At the same time expected proceeds from burglary (targeted at undefended HQ houses) start to fall, relative to the marginal criminal's income, and a lower level of crime emerges. Appendix A shows that this is indeed the case under the additional assumption that $F'(\bar{y})$ is positive but 'small'. Hence we conclude:

Corollary 3 to Theorem 3. *Richer neighborhoods may have lower crime rates than poorer neighborhoods because the richest households in the richer neighborhoods adopt an effective defence technology against burglary.*

6. Conclusions

It seems reasonable to expect that the level of property crime will be influenced in some way by the distribution of income (and wealth). We have presented here a theoretical economic model which traces a potential link between worsening income inequality and increases in the number of burglaries, using the Lorenz and 'relative differential' comparisons of income distributions. The most powerful result (Theorem 3) says simply that increases in relative differential inequality increase the level of crime, and has allowed us to show how the level of crime may be higher under regressive taxation (Section 4) and in richer neighborhoods (Section 5).

There seems to be no lack of potential for further work on related issues. On the one hand, it would be of interest to see if there is any recent direct empirical support for the relation between income inequality and burglary suggested here, and to explore more generally empirical links between income distribution and the various categories of property crime. On the other hand, theoretical developments which relax some of our assumptions (e.g., the restriction to two house types, the exogenous arrest probability) and which encompass dynamics (and hence repeat victimization—see footnote 5 and/or the incapacitation effect—see footnote 1), explicit modelling of offender–offence locations (see footnote 4), welfare questions (police resourcing issues, income redistribution due to crime, etc.) and defence technologies (as initiated in Section 5) come to mind as possibly worthy of investigation from the base provided here.

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Appendix A

Proof of Lemma 1. Since $c<v<1/2$ in equilibrium, class 2 must be nonempty with a measure of at least $(1-2v)$, and hence a ratio of maximum to minimum income of at least δ. For an individual with income y to choose class 2, it must be true, in particular, that

$$U_2 \geq U_3 \Leftrightarrow y \geq \sigma(m(V)-r),$$

$$U_2 \geq U_1 \Leftrightarrow \mu(1-q\beta)r \geq y[\mu(1-q\beta)-1] \text{ where } q=c/v.$$

Now $\mu(1-q\beta)-1>0$ in equilibrium, otherwise $U_2<U_1$ for all y and class 2 is empty. Defining

$$y^c=\sigma(m-r) \text{ and } y^v=\frac{\mu r(1-q\beta)}{\mu(1-q\beta)-1},$$

it is necessary in equilibrium that $y^c<y^v$ and any class 2 income $y\in[y^c, y^v]$. We now show that under the parameter restrictions of Assumption 1,(i) $U_2>U_4$ at $y=y^c$, and(ii) $U_2>U_4$ at $y=y^v$.Under (i) and (ii) the linearity of each U_i in y ensures that the equilibrium class structure is as claimed. It must then be that $y^v=F^{-1}(1-v)$ so that the housing market clears. To prove (i) and (ii), note that $U_2>U_4$ at y iff

$$y>\mu(1-p)(1-q\beta)(y-r)+\beta\mu(1-p)(m(V)-r),$$

or replacing r in $y-r$ by $y^{v}[\mu(1-q\beta)-1]/[\mu(1-q\beta)]$, replacing $m(V)-r$ by y^{c}/σ and rearranging,

$$[\mu(1-q\beta)-1]y^{v} > y\left[\mu(1-q\beta)-\frac{1}{1-p}\right]+\mu\beta\frac{y^{c}}{\sigma}. \tag{4}$$

Introducing $y=y^{c}$ into (4), (i) is true iff

$$\frac{y^{v}}{y^{c}} > \frac{\mu(1-q\beta)-\dfrac{1}{1-p}+\dfrac{\mu\beta}{\sigma}}{\mu(1-q\beta)-1}. \tag{5}$$

Since $y^{v}/y^{c}>\delta$, the parameter assumptions ensure (5) if they ensure that δ exceeds the right hand side of (5), an inequality which, after rearrangement and using $q<1$ is ensured if

$$\sigma(\delta-1)(\mu-1) > \beta[\mu-1+\sigma\mu(\delta-1)],$$

which follows from Assumption 1 and so (i) follows.

Now introducing $y=y^{v}$ into (A), (ii) is true iff $y^{v}/y^{c}>\mu$, which is ensured again by Assumption 1, so that (ii), and hence the required class structure follow. (EA) and (EB) follow from the definitions of y^{c} and y^{v} given earlier, substituting $q=F(y^{c})/v$ and rearranging in the definition of y^{v} to produce (EB). □

Proof of Corollary 3. An equilibrium for G would be x^{c}, r, q with a marginal adopter's income $x^{a}\in[\rho F^{-1}(1-v),\ \rho\bar{y}]$ where households with incomes in $[x^{a}, \rho\bar{y}]$ adopt, such that

$$\text{(EA) } x^{c}=\sigma[\rho\phi(x^{a}/\rho)-r],$$

$$\text{(EB) } F(x^{c}/\rho)=\frac{F(x^{a}/\rho)-(1-v)}{\beta}\left(1-\frac{\rho F^{-1}(1-v)}{\mu[\rho F^{-1}(1-v)-r]}\right),$$

$$\text{(EC) } a=\frac{\beta F(x^{c}/\rho)(x^{a}-r)}{F(x^{a}/\rho)-(1-v)},$$

where $F(x^{a}/\rho)-(1-v)$ is the fraction of households in G with incomes between $\rho F^{-1}(1-v)$ and x^{a}; and

$$\phi(y^{a})=\frac{\displaystyle\int_{F^{-1}(1-v)}^{y^{a}} y\,\mathrm{d}F}{F(y^{a})-(1-v)},$$

is the mean income in f of households with incomes between $F^{-1}(1-v)$ and y^{a}, so $\rho\phi(x^{a}/\rho)$ is the mean income of households in G with incomes between $\rho F^{-1}(1-v)$ and x^{a}; and (EA)/(EB)/(EC) then correspond to the optimality conditions for the marginal criminal/HQ-owner/adopter, respectively. If, for ρ near (and greater than) unity, a solution to (EA)–(EC) can be found, in which x^c is near $\hat{y}^c$, r is near $\hat{r}$ and $x^a \le \rho\bar{y}$ is near $\bar{y}$, then the analogue of (E5) continues to hold (and burglars target undefended HQ houses), the housing market clears and individual decisions on crime, housing and adoption will be optimal. Such a solution is then an equilibrium for G. Using the additional assumption that $F'(\bar{y})$ is positive but 'small', we now show that such solutions to (EA)–(EC) can indeed be found (for β sufficiently small).

From (EA)–(EC), define the following functions:

$$\psi_1(x^c, x^a, r, \rho) = x^c - \sigma[\rho\phi(x^a/\rho) - r],$$

$$\psi_2(x^c, x^a, r, \rho) = \beta F(x^c/\rho) - [F(x^a/\rho) - (1-v)]\left(1 - \frac{\rho F^{-1}(1-v)}{\mu[\rho F^{-1}(1-v) - r]}\right),$$

$$\psi_3(x^c, x^a, r, \rho) = \beta F(x^c/\rho)(x^a - r) - a[F(x^a/\rho) - (1-v)].$$

We know $\psi_i(\hat{y}^c, \bar{y}, \hat{r}, 1) = 0$, $i = 1, 2, 3$ by assumption on the F equilibrium. We may extend F (as a function, but not a distribution function) in a twice continuously differentiable fashion to the right of $\bar{y}$, in which case each ψ_i is twice-differentiable at least on some neighborhood of $(\hat{y}^c, \bar{y}, \hat{r}, 1)$. Evaluating derivatives of each ψ_i at $(\hat{y}^c, \bar{y}, \hat{r}, 1)$ leads to the following Jacobian:

$$J = \begin{bmatrix} \frac{\partial\psi_1}{\partial x^c} & \frac{\partial\psi_1}{\partial x^a} & \frac{\partial\psi_1}{\partial r} \\ \frac{\partial\psi_2}{\partial x^c} & \frac{\partial\psi_2}{\partial x^a} & \frac{\partial\psi_2}{\partial r} \\ \frac{\partial\psi_3}{\partial x^c} & \frac{\partial\psi_3}{\partial x^a} & \frac{\partial\psi_3}{\partial r} \end{bmatrix} = \begin{bmatrix} 1 & \frac{\sigma}{v} F'(\bar{y})(\bar{y} - m(V)) & \sigma \\ \beta F'(\hat{y}^c) & -F'(\bar{y})\left(1 - \frac{F^{-1}(1-v)}{v[F^{-1}(1-v) - \hat{r}]}\right) & \frac{v}{\mu} \frac{F^{-1}(1-v)}{[F^{-1}(1-v) - \hat{r}]^2} \\ \beta F'(\hat{y}^c)(\bar{y} - \hat{r}) & \beta F(\hat{y}^c)\left[1 - \frac{\beta}{v} F'(\hat{y}^c) F(\hat{y}^c)(\bar{y} - \hat{r})\right] & -\beta F(\hat{y}^c) \end{bmatrix}.$$

Letting M_{ij} denote the minor of the (i, j) element of J, we can be sure that $M_{32} > 0$ for all β smaller than some positive value, β_1 say. If $F'(\bar{y}) > 0$ (which we assume), it also follows that $M_{31} < 0$ for all β smaller than some positive value β_2, say. Fix $\beta \le \min\{\beta_1, \beta_2\}$. We may now reduce $F'(\bar{y})$ to any positive level without affecting $\hat{y}^c$, $\hat{r}$, or $m(V)$, and we assume that $F'(\bar{y})$ is sufficiently small that (expanding by column 2) det $J < 0$. By the implicit function theorem, there are continuously differentiable functions $x^c(\rho)$, $x^a(\rho)$, $r(\rho)$ for ρ in some neighborhood of 1, such that these x^c, x^a, r solve (EA)–(EC).

Now differentiating (EA)–(EC) with respect to ρ, setting $\rho = 1$ and rearranging produces

$$J \cdot \left[\frac{\partial x^c}{\partial\rho} - \hat{y}^c \;\; \frac{\partial x^a}{\partial\rho} - \bar{y} \;\; \frac{\partial r}{\partial\rho} - \hat{r}\right]^{\mathrm{T}} = [0 \;\; 0 \;\; -\beta F(\hat{y}^c)(\bar{y} - \hat{r})]^{\mathrm{T}},$$

By Cramer's rule,

$$\frac{\partial x^c}{\partial \rho} - \hat{y}^c = -\frac{\beta F(\hat{y}^c)(\bar{y} - \hat{r})M_{31}}{\det J} < 0,$$

and

$$\frac{\partial x^a}{\partial \rho} - \bar{y} = -\frac{\beta F(\hat{y}^c)(\bar{y} - \hat{r})M_{32}}{\det J} < 0,$$

The fact that $(\partial x^a)/\partial \rho < \bar{y}$ means that as ρ increases from 1, $x^a(\rho) < \bar{y}$, as required for equilibrium. That $(\partial x^c)/(\partial \rho) < \hat{y}^c$ means that the level of crime is lower in G, as required. □

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