The logic of costly punishment reversed: expropriation of free-riders and outsiders[*,†]

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Abstract

Current literature views the punishment of free-riders as an under-supplied public good, carried out by individuals at a cost to themselves. It need not be so: often, free-riders' property can be forcibly appropriated by a coordinated group. This power makes punishment profitable, but it can also be abused. It is easier to contain abuses, and focus group punishment on free-riders, in societies where coordinated expropriation is harder. Our theory explains why public goods are undersupplied in heterogenous communities: because groups target minorities instead of free-riders. In our laboratory experiment, outcomes were more efficient when coordination was more difficult, while outgroup members were targeted more than ingroup members, and reacted differently to punishment.

KEY WORDS: Cooperation, costly punishment, group coercion, heterogeneity

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1 Introduction

Deterring free-riding is a central element of social order. Most students of collective action believe that punishing free-riders is costly to the punisher, but benefits the community as a whole. Thus, punishment is itself a collective good, and so providing punishment means solving a second-order collective action problem (henceforth SOCAP). A society's primary task is to solve the SOCAP, and thus deter free-riding.[1]

We question this view. Punishing free-riders need not be costly. For, when enough people coordinate to punish somebody, the risks for the punishers are small, and they may benefit materially by forcibly appropriating a fraction of their victim's income or economic assets ("expropriation" for short). In these cases, punishment is individually rational for the punishers and the threat of punishment is credible. Sanctioning free-riders is simply a matter of coordination.

Because coordinated expropriation can be profitable, it may be used to target free-riders, but it may also be used opportunistically. Thus, expropriation threatens a second element of social order, namely secure property rights. Unusual, unpopular or vulnerable people may be falsely identified as free-riders and targeted. Furthermore, the threat of expropriation can make individuals unwilling to take risks or stand out, for example by individual enterprise (Platteau, 1996). By focusing on individual free-riding and ignoring collective expropriation, social scientists have misread the problems of self-governing communities. To achieve efficient outcomes societies must both punish individual free-riders, and prevent abusive expropriation.

We present a simple theory of group expropriation (a.k.a. confiscation, dispossession, disseizure, taking, or theft), and show how the possibility of profitable expropriation of individuals by coordinated groups can affect public goods provision. A key feature of the technology is the ease of expropriation, modeled as the minimum number of targeters that is required to successfully expropriate a victim. When a small group can do this, then coordination failures are less likely, and expropriation is more profitable, because the loot is shared among fewer people. This is true whether expropriation is targeted on free-riders or not. Ease of expropriation thus makes it easier to punish free-riders but also easier to target anyone else, and can therefore either help or harm efficiency. However, if coordination sometimes fails, and if free-riders are a *salient* target for expropriation, then there is a "sweet spot" where only free-riders are expropriated, both free-riding and expropriation are avoided along the equilibrium path, and outcomes are efficient. When expropriation is harder than this, it becomes impossible and free-riding occurs. When it

[1] Ostrom (1990) describes the "general problem" of common pool resource situations as "how to organize to avoid the adverse outcomes of *independent action* [our italics]" (p. 29) and argues "[s]ubstantial benefits have to be obtained to make costly monitoring and sanctioning activities worthwhile" (p. 36). See also Frohlich and Oppenheimer (1970); Oliver (1980); Yamagishi (1986).

gets easier, inefficient equilibria arise; in the extreme case, there is a Hobbesian anarchy, and outcomes are the worst possible.

Coordinated expropriation can explain why ethnically diverse communities may be less successful at providing public goods (Alesina, Baqir and Easterly, 1999, Alesina and La Ferrara, 2000, Easterly 2001*b*). Visible minorities may provide a convenient target to coordinate on. If a group targets ethnic minorities, this abuse leaves free-riders unpunished. We illustrate these points with historical evidence from the mining camps of the California Gold Rush, a test case where technologies made expropriation easy, amidst a very ethnically diverse population.

Lastly, we test the theory's predictions in a laboratory experiment: a public goods game, followed by a game of group expropriation. Treatments vary the ease of expropriation, and group diversity. In treatments where expropriation requires no coordination, we see both more expropriation and also more free-riding. "Minority" subjects, identified by a trivial observable difference from others in their group, are more likely to be targeted than others, and react differently to being dispossessed.

Section 2 outlines our arguments and discusses links with existing literature. Section 3 presents the theoretical model. Section 4 discusses group heterogeneity. Section 5 details our experiments. Section 6 concludes.

2 Group expropriation and the provision of punishment

Frohlich and Oppenheimer (1970) developed the idea of the SOCAP in response to Olson's (1965) statement of the problem of collective action.

> [T]he mechanism offered by some economists to explain the supply of collective goods does not represent a sufficient explanation [...] Suppose that a tax is collected through coercion. What is to prevent those who collect the tax from absconding with the proceeds? Any mechanism for insuring that revenues so collected are turned toward the supply of collective goods would itself be a costly collective good. (p. 120)

Oliver (1980) analyzed the problem formally and pointed out that the expected cost of punishment falls with the proportion of free-riders, and may thus be zero in equilibrium.

The SOCAP has helped to motivate two highly influential literatures. The first draws on the theory of repeated games. In an equilibrium of a repeated game, free-riding may be "punished" by reciprocating free-riding during future play (Axelrod and Hamilton, 1981; Fudenberg and Maskin, 1986). This idea has been taken up widely, beyond game theory, in explaining how communities function. Key works include Coleman (1988), Ostrom

(1990) and Ellickson (1994). The mechanism needs no special punishment motivations. Instead, individuals must have a low discount rate, expect future interactions over an indefinite horizon, and be informed about others' past behavior. Applied work often interprets this as requiring communities to have low levels of migration and plenty of gossip (e.g. Coleman 1988,Ostrom 1990).

The second literature responds to the SOCAP by arguing that humans provide coercion, despite its cost, because of an innate preference for punishing bad behavior. This idea is supported by experimental evidence that people will pay to punish free-riders even in one-shot games (Fehr and Fischbacher, 2004; Henrich, 2004; Henrich et al., 2006). A large body of theory characterizes costly punishment as an evolutionarily stable strategy, often invoking Oliver's mechanism (Boyd and Richerson, 1992; Boyd et al., 2003; Nowak and Sigmund, 2005). The experimental literature is even more extensive: Google Scholar records about 3680 articles using the phrase "costly punishment" since 2000.

Recently, however, this idea has been criticized. Motivations for costly punishment require strong conditions to evolve; costly punishment does not always increase efficiency in laboratory public goods games (Dreber et al., 2008); and a review of the anthropological literature shows that much free-riding is punished costlessly (Guala, 2012; see also Boehm 2001, Wiessner 2005). Lastly, the work of Rand et al. (2014) raises questions about the evidence for costly punishment motivations: costly punishment behaviour in lab experiments may not reflect a social preference, but a "social heuristic", carried over from real-world settings.

Here, we reexamine the assumption behind this work: the existence of the SOCAP. We start from three basic premises. Firstly, in many settings, individuals have expropriable assets. Punishment may involve inefficient conflict, but if the winner can *expropriate* ("disseize", "confiscate") assets or income from the loser, then the conflict may be *ex ante* profitable to one side. Second, punishment need not be provided by individuals; instead a group comprised of some or all other community members, can choose to target an individual. In many kinds of conflict between an individual and a group, when group size increases, the expected *total* harm to the group decreases, and the expected harm to the individual increases;[2] if so, a large enough group can cause harm to an individual at minimal risk to its members. Third, expropriation by a group requires group members to coordinate on a common target.

Under these conditions, groups will be able to expropriate individuals at a profit. This does not guarantee that free-riders will be punished, but it makes punishment a coordination problem, rather than a collective action problem. If some group can agree

[2]This follows from Lanchester's (1916) "square law" for physical conflict between an individual and a group. It is also consistent with the theory of e.g. trade wars, where larger countries or coalitions of countries can experience a net gain from retaliation against a small country.

on a strategy of targeting free-riders, free-riding will be deterred. But the group need not only target free-riders. It can coordinate to target anyone, irrespective of their behavior. Doing so profits the group, but subjects the community to inefficiencies from redistribution and conflict (Tullock, 1967). Therefore, social efficiency requires balancing two risks: if groups fail to coordinate, individual free-riding goes unpunished; if they coordinate in the wrong way, the innocent are expropriated (and free-riding may still go unpunished).

Expropriation of individuals by groups, or by the majority, is widespread. Historical examples include witchcraft accusations in Europe and America (Horsley, 1979; Evans-Pritchard and Gillies, 1976; Boyer and Nissenbaum, 1974), English popular culture (Thompson, 1992), and anti-semitism. Contemporary examples include riots and pogroms against economically successful minorities (Horowitz, 2001; Brass, 2004; Tambiah, 1996; Chua, 2004). In many cases, the victim's supposed misbehavior provides a pretext for "punishment" that is really driven by self-interest. In the US, lynchings of blacks may have been driven by inter-racial labour market competition (Beck and Tolnay, 1990; Raper, 1933). In Tanzania, elderly women are killed as witches when drought makes them a burden to their relatives (Miguel, 2005).

The possibility of expropriation depends on the characteristics of the assets to be appropriated and of the expropriation technology. Some forms of wealth are easier to expropriate than others. Productive assets such as land and buildings can be seized. Movable assets like currency are easier to preserve, and (barring slavery) human capital is inexpropriable. When technology favors the defensive, it takes a large group to expropriate someone. When it favors the offensive, a small group can do the job. In hunter-gatherer bands, the typical sanction is to ostracize offenders (Boehm, 2001); this must be done by the whole band. Among pastoralists, only a few individuals are required to seize someone's cattle.

Easier expropriation may lead to more expropriation. More subtly, ease of expropriation may affect whether expropriation is targeted on free-riders. Small groups can easily coordinate to disseize specific individuals, while large groups may need a public signal to coordinate. One possible signal is free-riding by the potential target. Pastoralist societies are often "segmented", with shifting allegiances, coalitions and feuds, and widespread cattle-raiding, suggesting a high level of arbitrary disseizure (Lewis, 1999; Evans-Pritchard, 1940). Mayshar et al. (2015) argue that cereal crops, which were easy to take, were linked to the emergence of a hierarchy in which a minority of individuals expropriated others (but also provided protection against bandits). The import of firearms and iron into the stateless societies of Guinea-Bissau caused a shift in expropriation technology, since iron was used for weapons. These societies began to participate in the slave trade. Judicial institutions were refashioned in order to meet demand: slaves were accused of crimes and found guilty by ordeal (Hawthorne, 1999).

The problems of collective expropriation may be particularly severe in ethnically diverse communities. Ethnic markers provide a natural coordination device for picking a target. Also, expropriators may be more willing to target members of an outgroup, since a rule of doing this protects them from being targeted themselves in future. These factors can encourage inefficient confiscation. Also, even if minorities are not in fact more likely to be targeted, they may perceive that they are, and therefore see less incentive not to free-ride. Minority targets of sanctions face a difficult problem of causal identification: are they targeted for breaking the rules, or because of who they are? Not surprisingly, different groups often disagree radically about the interpretation of particular events. These factors can explain why diverse communities are often less successful at providing public goods (Alesina, Baqir and Easterly, 1999; Alesina and La Ferrara, 2000; Easterly, 2001*b*)).

Some parts of our argument relate to existing work. The successful "common pool resource" systems analyzed in Ostrom (1990) often used fines as sanctions. Other authors have examined group coordination as a means of punishing free-riders. Weingast (1997) models how citizens can coordinate to preserve the rule of law against infringements by rulers. Experiments on coordinated punishment in public goods games include Casari and Luini (2009). Abbink and Doğan (2016) show that groups may coordinate to expropriate vulnerable individuals. The theoretical literature on anarchy analyses individuals' choice to invest in production or in coercion (Skaperdas, 1992). Friedman (1999) argues that modern societies use inefficient punishments such as imprisonment, rather than efficient punishment such as fines, because efficient punishments may induce rent-seeking.

Classical theorists were aware of group expropriation. Hobbes' analysis of anarchy in the State of Nature starts from expropriation by groups:

> ...the weakest has strength enough to kill the strongest, either by secret machination, or *by confederacy with others*, that are in the same danger with himselfe... if one plant, sow, build, or possesse a convenient Seat, others may probably be expected to come prepared *with forces united*, to dispossesse, and deprive him, not only of the fruit of his labour, but also of his life, or liberty. [our italics]

A more optimistic view, held before and after Hobbes, was that Natural Law might govern behavior in the State of Nature. The right to punish breaches of Natural Law was common to all humans; the problems of the State of Nature arose when humans failed to apply this right impartially.[3] We see our contribution as returning to this classical idea, analyzing how humans may both use expropriation to punish free-riding, and abuse it out of self-interest.

[3] See Locke *Second Treatise* sec. 13; Hooker *Laws of Ecclesiastical Polity* Book I X.4.

3 A formal model

N actors are each endowed with e units of wealth, and interact in two stages: a voluntary contribution stage, followed by a "expropriation" stage.

In the voluntary contribution stage, each actor i chooses to contribute $p_i \in [0, \bar{p}]$ to a common fund, with $\bar{p} \leq e$. The value of the fund is then multiplied by π, with $1 < \pi < N$, and divided equally among the group. Player i now has interim wealth of $w_i^G(p) = e - p_i + (\pi/N)\sum p_j$. Contribution decisions are public.

In the subsequent expropriation stage, each actor i chooses a target $x_i \in \{0, 1, ..., i-1, i+1, ..., N\}$, where $x_i = 0$ means that i chose not to target anyone, and $x_i > 0$ means that i chose to target actor x_i. Everyone observes all targeting choices. The private cost each actor incurs for targeting an individual, *irrespectively of whether or not expropriation is successful,* is $k \geq 0$; this may be a material cost or, equivalently, an unobservable "psychic" or "moral" cost.

Unless a player is targeted by at least $M \geq 1$ other actors, targeting fails. If one actor, j, is targeted by $T \geq M$ individuals, then j is successfully expropriated. An amount f is confiscated from his interim wealth, and the targeters each receive $(f-l)/T$, $l < f$, where l reflects an efficiency loss from expropriation (e.g. from costly conflict). The loss f reflects how much of each individual's wealth is expropriable; we assume that $f < e - \bar{p}$, so that at least f is always available from a player's interim wealth. The threshold M is a key parameter. It reflects the degree of coordination required to expropriate someone, due to the underlying "expropriation technology" discussed above. If $M > N/2$, then at most a single target can be expropriated. If $M = 1$, any individual can expropriate any other.

The contribution that i's targeting choice makes to i's payoff, as a function of the targeting choices of other individuals, is therefore

$$a_i = \begin{cases} (f-l)/T^j - k & \text{if } x_i = j \neq 0 \text{ and } T^j \geq M, \\ -k & \text{if } x_i = j \neq 0 \text{ and } T^j < M, \\ 0 & \text{if } x_i = 0; \end{cases} \tag{1}$$

where $T^j \equiv \sum_i \mathbb{1}_{[x_i = j]}$ is the number of players who targeted j. The contribution to i's payoff from other individuals targeting i is

$$v_i = \begin{cases} -f & \text{if } T^i \geq M, \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

The payoff accruing to i from a profile of targeting choices $x = (x_1, ..., x_N)$ is then

$$w_i^E(x) = a_i + v_i. \tag{3}$$

The total payoff to i from both stages is $w_i^G(p) + w_i^E(x)$.

3.1 Equilibrium

We restrict attention to sub-game perfect equilibria of the above game.

Proceeding by backward induction, we focus first on the last stage. Define

$$\bar{T} = \max_{T \in \{M,\ldots,N-1\}} T \text{ such that } (f-l)/T \geq k. \tag{4}$$

For $M > 1$, expropriation requires coordination, and so targeting is *not* a strictly dominant strategy for any positive k, and equilibria without expropriation are always possible. Also, if M is too large, expropriation cannot be gainful. Specifically:

1. if $(f-l)/M < k$, expropriation does not pay, and so nobody targets anyone in equilibrium;

2. if $(f-l)/M \geq k$ and $M = 1$, then in all equilibria, every player is targeted by exactly one other player (because the net gain from choosing a unique target exceeds that from choosing the same target as others);

3. if $(f-l)/M \geq k$ and $M > 1$, then expropriation requires coordination. In this case, a strategy profile is an equilibrium if and only if (a) nobody targets himself; (b) all expropriating groups have between M and $\bar{T}$ members inclusive; (c) no two expropriating groups differ in size by more than 1; (d) if any player is not targeting somebody, then all expropriating groups have exactly $\bar{T}$ members.

(Proofs are in the appendix.)

For $k = 0$, the set of equilibria with $M = 1$ is unchanged. With $M > 1$, any strategy profile is an equilibrium if and only if (a) all expropriating groups have either $M-2$ or less members, or between M and $N-1$ members; (b) no two *successful* expropriating groups differ in size by more than 1; and (c) if any player is not in a successful expropriating group, then there is either no successful expropriating group, or a single successful expropriating group of $N-1$ members. (Proof in the appendix.)

We might reinterpret "individuals" in the model as referring to small groups that always succeed in coordinating on the best outcome for them. If so, then $M = 1$ corresponds to the case where any such group can dispossess any other. The result is a Hobbesian anarchy where expropriation is universal.

If second-stage actions are not conditioned on first-stage actions, then the only equilibrium in the first stage has $p_i = 0$, $\forall i$. However, second-stage strategies can be conditioned on first period strategies, and this may allow for equilibrium contributions of $p_i > 0$. For a given profile of contribution choices $p = (p_1, ..., p_N)$, let $x(p) = (x_1, ..., x_N)$ be the corresponding profile of targeting decisions, and let p^* be the profile of contribution decisions actually played in equilibrium. An equilibrium of the whole game is then a pair $(p^*, x(\cdot))$ satisfying two conditions:

1. For all p, $x(p)$ is an equilibrium of the expropriation stage, as defined above.

2. Given $x(\cdot)$, no possible deviation p'_i is profitable for any player, i, i.e.

$$(1 - \pi/N)(p'_i - p^*_i) \geq w^E_i(x(p'_i, p^*_{-i})) - w^E_i(x(p^*)),$$

   where w^E_i is the payoff from the expropriation stage, as defined in (3).

For example, suppose that second-period strategies are as follows: if any individual i is a unique lowest contributor in the first stage ($p_i < p_j$ for all $j \neq i$), then a group of $\overline{T}$ individuals targets i in the second stage; otherwise no-one is targeted. Then, any first-stage symmetric contribution profile, $p_i = p_j \leq f/(1 - \pi/N)$ for all i, j, can be supported in equilibrium. More generally, if $M > 1$ any contribution profile with

$$p_i \leq f/(1 - \pi/N), \quad \text{for all } i, \tag{5}$$

(i.e. where contributions are less than the cost to the victim of conditional expropriation) can be sustained by targeting deviators.[4] Nevertheless, there remain continuation equilibria where no expropriation takes place in the second stage, or where confiscation is not conditioned on contribution levels, or is conditioned in the "wrong" way (e.g., where a group targets the highest contributor, rather than the lowest; or it targets an individual at random, or on the basis of payoff irrelevant characteristics). For all of these continuation equilibria, the only individually-rational level of contributions in the first stage is zero, and so the only first-stage equilibrium strategies are $p_i = 0$, $\forall i$. Similarly, if $M = 1$, then since every player is always expropriated in all subgames, contributions must be zero.

Equilibria cannot be Pareto-ranked. However, confiscation is "socially inefficient" in that it entails a deadweight loss l. More precisely, maximizing the *ex ante* expected payoff of a representative individual requires averting expropriation (i.e., if side payments were allowed, then Pareto optimality would exclude expropriation). In order to to be socially efficient in this sense, equilibria must feature expropriation only off the equilibrium path. Thus, an efficient equilibrium consists of every player contributing $\bar{p}$ in the first stage and no expropriation occurring in the second stage – supported by out-of-equilibrium strategies

[4] An equilibrium where targeting choices are conditioned on observed defections could also be thought of as incorporating a *correlated* equilibrium (Aumann, 1974) in the second stage, with visible defection acting as a signal that players use to make their strategies correlated.

whereby an individual that deviates from $\bar{p}$ in the first stage would be expropriated. From the equilibrium conditions and (5), the conditions required for an efficient equilibrium to be possible, for $M > 1$, are

$$(f - l)/M \geq k, \tag{6}$$

i.e. the minimum group size for expropriators, M, the cost of targeting k, and the size of expropriable assets make expropriation profitable; and

$$f \geq (1 - \pi/N)\bar{p}, \tag{7}$$

i.e. expropriable assets are sufficiently large relative to the public good level, $\bar{p}$.

So, under suitable conditions, efficient outcomes can be sustained. However, there are also many inefficient equilibria, with low contributions and/or confiscation occurring on the equilibrium path. As detailed in Appendix 1, this indeterminacy may be resolved if players' choices are boundedly rational: if players can make "mistakes" in their choice of target, being the lowest contributor can act as an observable marker that makes an individual salient as a potential target and reduces targeting mistakes. Then defectors may become a comparatively "safer bet" for targeting, and the only continuation equilibria where expropriation is sustainable may be those where defectors are targeted, making it possible to rule out socially inefficient equilibria.

3.2 Discussion

Punishment that is gainful for the punishers eliminates the second-order free-rider problem but introduces a new one: opportunities to confiscate resources from non-defectors. Under fully rational play, nothing makes defectors more "likely" targets for expropriation. But boundedly rational players may use defection as a marker for targeting. If so, and if coordination is easy but not too easy, then only defectors can be expropriated in any equilibrium.

This model abstracts from some features of the real world. First, it may be costly to detect free riding, and expropriation may require upfront costs, such as investment in coercive power. However, the presence of such costs does not change our conclusion that public goods provision can be supported by expropriation. To see this, alter the game above, so that nobody can be expropriated unless total contributions of at least $q > 0$ are provided in the public goods game. Now, suppose that, in the original game, there was an equilibrium with contributions $p = (p_1, ..., p_N)$, such that for any player i, $\sum_{j \neq i} p_j \geq q$. Then contributions p can be supported in the new game, using exactly the same strategies. For, a player who deviates to contributing zero cannot reduce total contributions below q, and therefore still faces expropriation.

Second, free-riders may offer side payments to ward off expropriation. For example, the successful common pool resource management systems analyzed in Ostrom (1990) often used fines as punishments. Suppose that an individual who faces being expropriated can bargain with the group targeting him. They will agree some transfer between $f-l$ and f, which will benefit both sides since no resources are destroyed. Expropriators will get more while the target pays less. This may increase the maximum group size in (4), loosen the constraint on expropriation $(f-l)/M \geq k$, and decrease the maximum contribution levels in (5). However, the basic insights of the model are unchanged. Similarly, if the cost of targeting k depends on the size of the targeting group, the constraint on expropriation will become more complex without changing the model much.

Finally, individuals can be heterogenous along a number of dimensions. We discuss the implications of this next.

4 Group heterogeneity

Asymmetries across individuals with respect to payoff-relevant parameters can give rise to asymmetries in targeting choices. If f, l or k are different for different expropriation targets, then condition (6) may only hold for some individuals, and so only those individuals can face punishment. For example, if only some individuals have expropriable amounts f_i satisfying (6), then in the most efficient equilibrium, they will each contribute $p_i = f_i/(1-\pi/N)$ under threat of expropriation if they do not, while others will not contribute.

If there are asymmetries but (6) is still satisfied for all individuals, then, under fully rational play, those asymmetries do not change the set of equilibria. Under boundedly rational play, however, any visible marker that identifies some individuals, may make them salient targets for expropriation, irrespective of their behavior. For example, ethnic riots may target minority businesses for looting.

If visible differences are salient, individuals may use them, rather than free-riding, to coordinate on targets.This applies whether the visible marker is payoff-relevant (e.g. a higher f_i) or not (e.g. ethnicity).[5] This will make equilibria with inefficient expropriation more likely and efficient equilibria less likely. If so, then less homogenous societies will find it harder to prevent free-riding. Indeed, ethnically diverse communities appear to be less successful at providing public goods (Alesina, Baqir and Easterly, 1999; Alesina and La Ferrara, 2000; Easterly 2001*b*; Habyarimana et al., 2007; Habyarimana, Humphreys and Posner, 2009).

[5]It is also not incompatible with majorities blaming their actions on minorities' bad behaviour: in fact, that is typical of intergroup violence (Horowitz, 2001).

The problems of ethnically divided societies are often thought to lie in deep cultural differences. However, even when there is a strong shared culture, or where different cultural norms are mutually well-understood, the mere fact of visible difference may be enough to make one group a target. For example, in Bosnia, Muslims, Serbs and Croats lived in mixed villages and, while maintaining cultural differences, also shared identities as villagers, and were knowledgeable about each others' customs (Bringa, 1993); yet, during the Yugoslav conflict, after politicians used the media to demonize outgroups, different identities swiftly became a basis for conflict (Oberschall, 2000; Bozic-Roberson, 2004). In the terminology of Habyarimana et al. (2007), our explanation for ethnic divisions relies on "equilibrium selection" rather than on deep underlying preferences.

The California Gold Rush shows how group heterogeneity can interfere with informal enforcement. The Gold Rush started in 1849 when gold was discovered in the territory, shortly after California was ceded to the United States. The legal status of gold claims remained unclear until 1866, and state authority was distant or absent in the California territory: there was no police force, and in the first years even the identity of the legal authorities was unclear. So, miners had to make and enforce their own rules. As early histories of the Gold Rush emphasized, they did so successfully. Americans, with experience of democratic institutions such as the town meeting, set up "miners' meetings" to allocate property rights and make other rules. The camps were not a Hobbesian war of all against all, but an ordered anarchy (Umbeck, 1977; Zerbe and Anderson, 2001). Property rights – "claims" to a particular area – were enforced by the majority. A miner who violated others' claims could expect to have his own claim considered nonexclusive and open to jumpers, in an example of punishment as expropriation. Other crimes were also collectively punished by the population after short and informal trials (Howe, 1923).

Not all camps were equal, though. The Gold Rush drew in a wide array of nationalities, from Europeans fleeing post-1848 persecutions to "Chileans" (i.e. Latin Americans) and Chinese. Stewart (2009) gathers evidence on twenty-five early mining camps, and shows that ethnically homogenous camps were more likely to succeed at enforcing property rights. His explanation is that members of different ethnic groups were less willing to cooperate, due to different norms and lower altruism towards outgroup members, or less able to cooperate and coordinate, due to cultural and linguistic differences. These are the standard explanations described in the previous section. But newer historical work suggests a further reason. There was a dark side to mining camp law. Since rule violators could have their own claims expropriated, groups of miners faced a temptation to accuse others of violations. Punishment of rule-breakers shaded into arbitrary expropriation. Non-Anglo-Americans were particularly often targets: "[t]he French, the Spanish Americans, and the Chinese each tended to be separate elements in the population.... from an early date the majority displayed toward these nationalities a persistent antagonism that was easily triggered into bullying, persecution and ostracism" (Paul, 1980). A classic example is the "Chilean war" of 1849:

> Anglos had begun mining some dry diggings that Chileans had worked earlier, and when the latter returned for the winter the two groups soon were at odds. In a called meeting the Anglos formed a mining district and drafted regulations, beginning with "No foreigners shall be permitted to work at these mines."... (Paul 1980, p. 241).

Ramon Gil Navarro, an Argentinian miner, described the affair: "Twenty-two Americans came over to the camp of the Chileans and had coffee with them.... While they were doing this, they went about taking the weapons of the Chileans without their noticing.... They were all taken to the house of the judge, who extorted 150 ounces of gold from them." Later there was a pitched battle between Chileans and Anglo-Americans; Chileans were arrested and brought before a judge, three were hanged and others possibly had their ears cut off. Each of these sides had their own "judge" to legitimize their actions (Navarro, 2000). The failure of ethnically diverse mining camps was not only due to individual free-riding, but also to rampant expropriation of minority group members by the majority group.

5 Experiment

Our model has multiple equilibria. To learn which are likely to be played, we study behavior in a laboratory experiment. The main treatment has a public goods stage followed by a expropriation stage. We vary the minimum group size for successful expropriation. We also vary the heterogeneity of groups, using a minimal marker of group identity – randomly assigned, payoff-irrelevant color labels.

Subjects were randomly allocated into groups of four. Each subject was given a color label (purple or green), which stayed the same throughout the experiment and was visible to other group members. They stayed in the same group throughout the experiment. They played twenty rounds. In our baseline, treatment PX, each round took place as follows.

First, the group of four played the public goods stage, which was a standard linear public goods game. Each subject was endowed with 50 Experimental Currency Units (ECU) and could contribute them to a common fund; total contributions were multiplied by 1.4 before being divided equally among the group; feedback on individual contributions was given.

Next, the group played the expropriation stage. Each subject was endowed with a further 50 ECU. Each subject could target either a single other group member, or nobody;

Treatment	Description	N groups
PX	Baseline: Public goods stage followed by expropriation stage	16
P	Public goods stage only	8
X	Expropriation stage only	6
PX-M3	As PX	16
PX-M2	Expropriation successful if two or more subjects targeted same person	15
PX-M1	Expropriation successful if one or more subjects targeted same person	14
PX-Het	As PX treatment, one minority subject per group	16
P-Het	As P treatment, one minority subject per group	8
X-Het	As X treatment, one minority subject per group	7
PX-Hist	10 rounds confiscation stage only, 10 rounds as PX	12
PX-Noise	As PX, noise added to contribution reports	8
PX-Stranger	As PX, groups rematched between rounds	9*
PX-Hist-Het	As PX-Hist, one minority subject per group	11
PX-Noise-Het	As PX-Noise, one minority subject per group	5
PX-Stranger-Het	As PX-Stranger, one minority subject per group	9*

* 9 matching groups defined by session/treatment

Table 1: Treatments

targeting involved no monetary cost. If at least three subjects targeted the same subject, the target was "expropriated", losing 50 ECU, and the expropriators each gained 15 ECU. Lastly, subjects learned how many people targeted each group member. This treatment implements our theoretical model, with $N = 4$, $M = 3$, $e = 100$, $\bar{p} = 50$, $\pi = 1.4$, $f = 50$, $l = 5$ and $k = 0$.[6] We introduce variants of this treatment below. Table 1 summarizes the different treatments. Appendix 2 describes the order in which treatments were run.

After each experiment finished, subjects answered a short questionnaire and were paid privately for one randomly chosen round, at a rate of 1 ECU = 10 UK pence, plus a £2.50 show-up fee. Sessions were run at two UK universities from June 2013 to May 2016, using zTree (Fischbacher, 2007). Subjects were invited using the hroot subject pool management software (Bock, Nicklisch and Baetge, 2012). In total 712 subjects took part in 47 sessions. Sessions lasted about one hour. Average earnings were £13.33.

5.1 Free-riding and coordinated expropriation

We first focus on a central idea of this paper: the threat of expropriation can increase public goods contributions, but the presence of a public goods problem can justify higher

[6] Costless targeting, $k = 0$, introduces some extra equilibria which we discuss in the appendix. However, note that there may be a psychological cost of targeting an individual (e.g. shame).

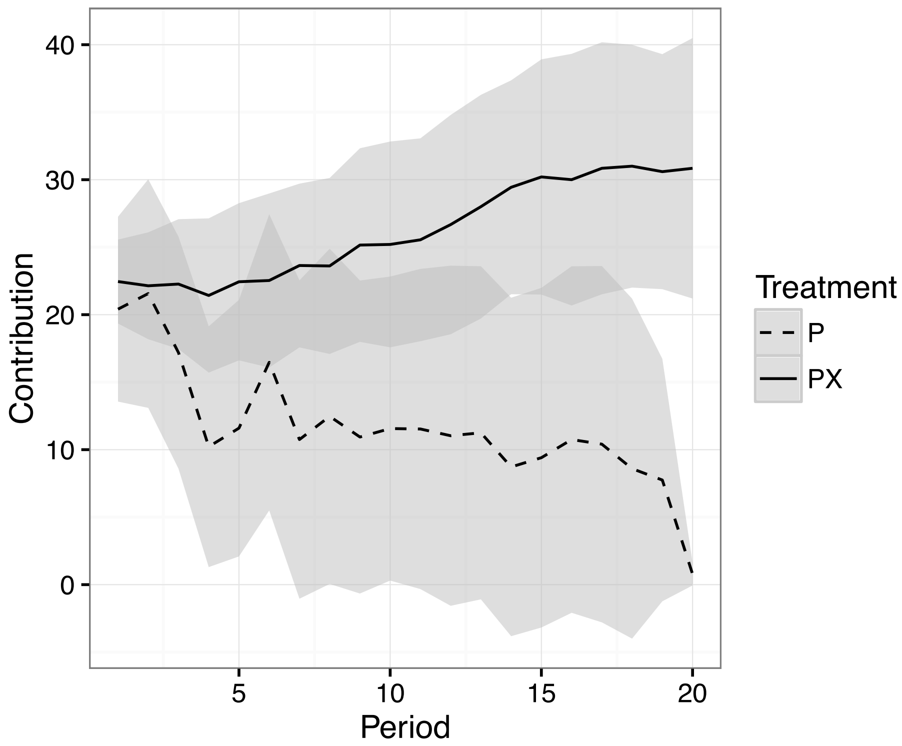

Figure 1: Mean contributions over time, treatments PX and P. Shaded areas are 95% confidence intervals

levels of expropriation. In the experiment, the benefit of higher contributions outweighs the deadweight cost of expropriation (just 5 ECU). However, we do not know the relative cost of expropriation in field settings, so it is important to analyze each dimension separately. To do so, we compare our baseline treatment PX against two alternatives. In treatment P, each of the 20 rounds consisted of the public goods stage on its own, without a subsequent expropriation stage. In treatment X, each round consisted of the expropriation stage on its own, without a preceding public goods stage.

Result 1. *Contributions to the public good were significantly higher in the PX treatment than in the P treatment.*

Figure 1 shows mean public goods contributions over time in these treatments. Mean contributions per group are significantly higher in PX than P (26.20 vs. 11.67, $p < 0.05$; tests are Mann-Whitney tests at group level unless otherwise stated).

Result 2. *There were significantly more expropriations in PX than in X treatments.*

The mean number of expropriations in a group was 9.62 in PX vs. 2.67 in X ($p < 0.01$).

We next confirm that expropriation was indeed targeted on low contributors.

Result 3. *In the PX treatment, at individual level, lowest contributors were more likely to be targeted.*

The second column of Figure 3 shows that a group's unique lowest contributor in a round was more likely to be expropriated than not; a non-unique lowest contributor faced a small risk of expropriation; and other people were almost never expropriated.[7]

Result 4. *In the PX treatment, at group level, mean contributions were positively correlated with expropriations.*

If some groups successfully use expropriation to threaten low contributors, then at group level, more expropriation should be associated with higher contributions, as in public goods games with costly punishment (Fehr and Gachter, 2000). Indeed, across PX groups, the correlation between number of successful expropriations and average contributions was 0.608 ($p < 0.05$).[8]

5.2 Varying minimum group size for expropriation

With a minimum size of $M = 3$, expropriation appeared beneficial on balance. We now examine how changes in M affect contributions and expropriation levels. Our argument and model suggested that larger groups might be more likely to coordinate on free-riders rather than picking victims arbitrarily. Treatments PX-M1, PX-M2 and PX-M3 set M to 1, 2 and 3 respectively. In each case, if M or more subjects picked a single victim, that person lost her endowment of 50 ECU, and 45 ECU was shared among the expropriating group (so each expropriator got 45 ECU, 22.5 ECU or 15 ECU depending on the group size). PX-M3 is the same as the baseline PX. Treatments were balanced across groups within sessions.

Predictions from the model are as follows: under rational play, when $M = 1$, each individual is expropriated by one other individual irrespective of contributions, which are then zero. When $M = 2$ or $M = 3$, there are multiple equilibria including efficient equilibria with full contributions and no expropriation observed, as well as inefficient equilibria with or without expropriation. If players make mistakes with positive probability, as in our model of bounded rationality, then failure to coordinate will be more likely when $M = 3$. If this probability is lower when the target is a lowest contributor, then expropriation may be more targeted on low contributors for higher values of M.

Result 5. *Moving from PX-M3 to PX-M2 to PX-M1, contribution levels remained the same or decreased, while levels of expropriation increased.*

[7] About 32% of subjects were lowest contributors in a given round (16% unique lowest, 16% non-unique lowest). If all four group members contributed the same amount, we do not classify them as "lowest contributors".

[8] The correlation remains large and significant if we correlate expropriations in periods 1-10 with contributions in periods 11-20.

	PX-M1	PX-M2	PX-M3	p, PX-M1 vs -M2	p, PX-M1 vs -M3	p, PX-M2 vs -M3
Contributions	13.66	28.35	27.89	< 0.01	< 0.01	0.98
Expropriations	54.94	15.73	8.43	< 0.001	< 0.001	< 0.01
Attempts	75.44	59.00	61.29	< 0.01	< 0.01	0.97
Prop. exprop.: unique lowest	0.81	0.84	0.7	0.49	0.26	0.12
... non-unique lowest	0.68	0.19	0.06	< 0.001	< 0.001	< 0.01
... other	0.65	0.12	0.01	< 0.001	< 0.001	< 0.01

Table 2: Effects of varying minimum group size for expropriation

The first three rows of Table 2 show mean contribution levels, mean numbers of expropriations and numbers of expropriation attempts for the three treatments. Figure 2 plots contributions and expropriations. There were significantly lower contributions, more expropriations and more expropriations attempts in PX-M1 than the other treatments; and more expropriations in PX-M2 than PX-M3. Thus, a lower M was unambiguously worse: it led to weakly lower contributions, with strictly higher expropriation levels. The next two results tell why this was so.

Result 6. *When the minimum group size for expropriation was smaller, expropriation was less targeted on low contributors.*

Rows 4-6 of Table 2 shows the probability of being expropriated for unique lowest contributors, non-unique lowest contributors and others, along with significance tests. Unique lowest contributors were equally likely to be targeted in all treatments, but non-unique lowest contributors and others faced much more expropriation for smaller values of M.

Result 7. *Individuals reacted to expropriation by increasing their contributions only in PX-M2 and PX-M3 treatments.*

Table 3 regresses contributions on lagged contributions and on the number of group members who targeted the subject in the previous round. In treatment PX-M1, being expropriated by one or more group members had no effect. In treatments PX-M2 and PX-M3, those who were successfully expropriated increased their contributions. The largest effect is for expropriation by 3 group members in the PX-M3 treatment.[9]

In public goods experiments, making punishment easier typically leads to higher contributions (Fehr and Gachter 2000; Chaudhuri 2011). These results show a different pattern. Expropriation levels consistently rise as expropriation gets easier. By contrast, contributions are low when expropriation is impossible, as in treatment P, rise when it is possible (treatments PX and PX-M3), but then fall again if it is too easy (treatment PX-M1). The likely reason is that as expropriation gets easier, it gets less targeted on low

[9]Expropriation decisions may not be exogenous, even controlling for lagged contributions. As an alternative specification, we included *Period* and a dummy variable for being the unique lowest contributor in the previous round. Results were robust.

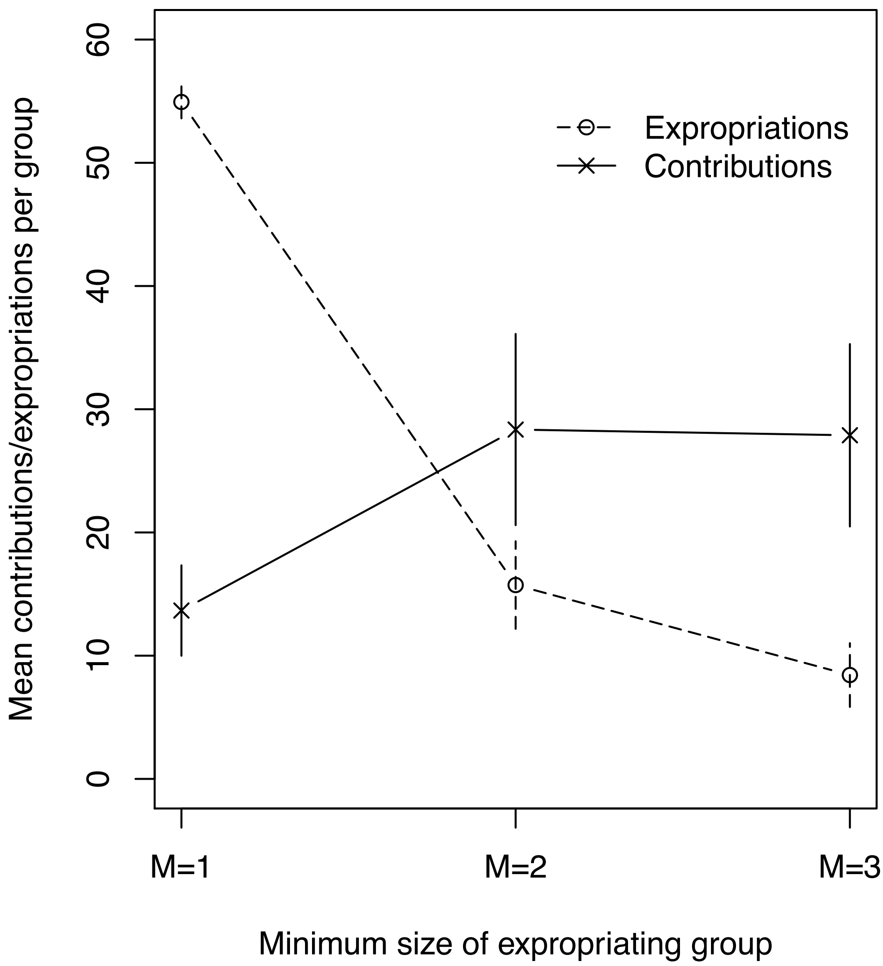

Figure 2: Expropriations and contributions in PX-M1, PX-M2 and PX-M3. Bars are 95% confidence intervals

	PX-M1	PX-M2	PX-M3
Intercept	4.02***	2.93**	6.20***
	(0.85)	(1.08)	(1.64)
Lag contrib.	0.64***	0.89***	0.78***
	(0.04)	(0.03)	(0.06)
Targeters=1	0.24	−0.17	−0.84
	(0.48)	(0.53)	(0.79)
Targeters=2	0.70	1.59*	−1.05
	(0.71)	(0.79)	(1.12)
Targeters=3	−0.04	3.75***	7.85**
	(1.51)	(1.04)	(2.56)
Num. obs.	1280	1200	1120
R^2	0.46	0.77	0.60
Adj. R^2	0.46	0.77	0.60
L.R.	784.17	1768.99	1037.83

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Robust s.e.s clustered by group.

Table 3: OLS regressions: individual contributions, treatments PX-M1/2/3

contributors. This fits the prediction of our model of bounded rationality and salience. It also appears that in PX-M1, individuals did not assume that being targeted was a result of low contributions, and hence did not raise their contributions.

5.3 Heterogenous groups

We argue that confiscatory punishment is particularly problematic in heterogenous societies, since minorities, rather than free-riders, might be targeted for expropriation. We tested this by introducing a minimal form of heterogeneity: a public, randomly assigned label with no payoff consequences or group manipulation.[10] Recall that in our experiment every subject was given a color label (purple or green), which stayed the same throughout the experiment and was visible to other group members. Instructions made clear that the label assignment was random. In treatment PX-Het, one subject within each group had a different color from the other three subjects. We call such subjects *minorities* and the other subjects the *majority*. In all other respects, PX-Het was the same as PX. Similarly, treatments P-Het and X-Het varied from treatments P and PX only by introducing a single minority subject.[11] This is a hard test for our theory: if even this weak form of heterogeneity affects behavior, then the same mechanism should work more strongly with highly salient real-world identities.

[10]Other experiments using this approach include Hargreaves-Heap and Varoufakis (2002), Efferson, Lalive and Fehr (2008) and Hargreaves Heap and Zizzo (2009).

[11]In all non "-Het" treatments, all subjects within a group had the same colour label.

As in the homogenous treatment variants, mean contributions per group are significantly higher in PX-Het than P-Het treatments (PX-Het 21.74 vs. P-Het 8.94). The group-level correlation between number of expropriations and average contributions in PX-Het was 0.685 ($p < 0.01$).

Result 8. *Contributions were not significantly different between PX and PX-Het treatments, nor between P and P-Het treatments.*

Although mean contributions are higher in homogenous than heterogenous groups, these differences are not significant (PX 26.20 vs. PX-Het 21.74, $p = 0.27$; P 11.67 vs. P-Het 8.94, $p = 1.00$). Thus, our mechanism alone was not enough to make heterogenous groups less efficient at public goods provision.

The next result shows that minorities were more likely to be targeted, as our theory suggests, but only in specific circumstances.

Result 9. *In treatment PX-Het, minorities were more likely to be expropriated than majorities only when they were non-unique lowest contributors.*

Figure 3 shows the proportion of subjects expropriated per round, grouped by both contribution and minority status. Expropriation was overwhelmingly targeted on lowest contributors in all treatments. *A unique* lowest contributor was especially likely to be expropriated.

Overall, there is no difference in the number of expropriations suffered by minority and majority individuals within PX-Het (minorities: 1.69, majorities: 1.62, $p = 0.34$). Minorities who were a lowest contributor, but not the unique lowest contributor, within a group were expropriated significantly more often (but note that contribution levels are not exogenous).[12] Thus, heterogenous groups appear to have only targeted minorities so as to coordinate on one of several equal lowest contributors. This supports our theory of minority salience, but only in a limited sense.

Result 10. *In treatment PX-Het, minorities and majorities increased their contributions equally after being expropriated.*

Next, we examine how individual contribution decisions responded to being expropriated. The first column of Table 4 regresses contribution decisions in PX-Het on lagged contribution decisions, and on the number of other group members targeting the subject (*Targeters*) in the previous round, interacted with minority status. Subjects may contribute more after being targeted by 1 or 2 others if they perceive a greater threat of future expropriation. Subjects react to being expropriated, or to being targeted by 2 other

[12] See the logit regression in the appendix.

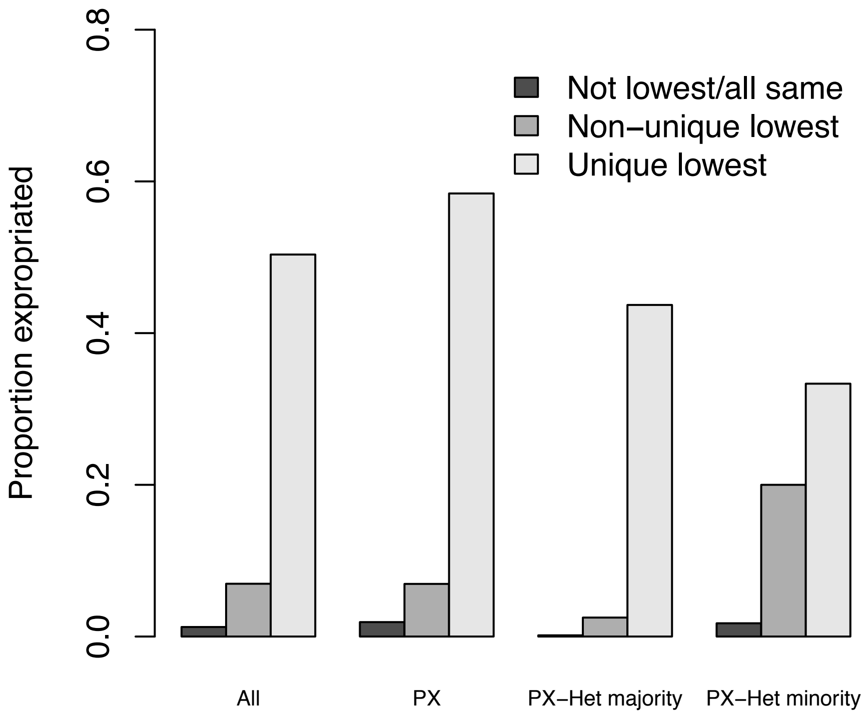

Figure 3: Proportion expropriated by minority status and contribution, PX and PX-Het

	PX-Het	PX-Hist-Het	PX-Noise-Het	PX-Stranger-Het
Intercept	3.66^{***}	2.40^{*}	3.45^{**}	4.07^{***}
	(0.85)	(1.16)	(1.34)	(0.85)
Lag contrib.	0.78^{***}	0.74^{***}	0.75^{***}	0.71^{***}
	(0.04)	(0.07)	(0.11)	(0.04)
Targeters=1	0.04	−0.93	0.40	−0.09
	(0.95)	(1.07)	(0.81)	(0.52)
Targeters=2	3.50^{**}	3.88^{*}	1.55	1.22
	(1.32)	(1.59)	(1.04)	(1.03)
Targeters=3	8.70^{***}	12.26^{***}	9.59^{*}	4.71^{**}
	(1.34)	(3.03)	(3.75)	(1.74)
Minority	0.18	0.87	0.25	0.35
	(1.12)	(0.96)	(1.23)	(0.94)
Minority x Targeters=1	1.16	−0.01	0.25	−1.70
	(1.50)	(1.87)	(1.69)	(1.17)
Minority x Targeters=2	−3.41	-5.61^{**}	1.10	−2.34
	(2.44)	(1.88)	(2.93)	(1.56)
Minority x Targeters=3	−1.89	-10.54^{*}	-7.07^{*}	−2.51
	(2.34)	(5.08)	(3.52)	(1.37)
Num. obs.	1277	396	400	1440
R^2	0.59	0.57	0.56	0.47
Adj. R^2	0.59	0.56	0.55	0.47
L.R.	1151.37	331.62	328.47	925.43

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Robust s.e.s clustered by group/matching group.

Table 4: OLS regressions of individual contributions

group members, by increasing their contributions. There is no evidence that minorities react differently from majorities: all interaction terms are insignificant.[13]

The above results support only parts of our story about heterogeneity. Participants did coordinate on minority group members, but only when they were one of two or more equal lowest contributors. Minority participants did not react differently to punishment than majorities. We ran further treatments to test the robustness of these results and to see under what conditions intergroup differences might emerge. These involved variations of the PX and PX-Het treatments.

PX-Hist and PX-Hist-Het sessions consisted of ten rounds of the expropriation game only (as in treatment X), followed by ten rounds of the public goods game plus expropriation game (as in treatment PX). Majorities might coordinate on targeting minorities in early rounds, and this might affect expectations in later rounds.

In PX-Noise and PX-Noise-Het treatments, we added an independent shock to each player's report of other players' contributions, so that different players would see different contribution levels. This mimicked a situation where levels of free-riding, and hence the reasons for expropriation, were uncertain and might be interpreted differently by different groups.

In PX-Stranger and PX-Stranger-Het treatments, subjects were rematched in new groups of 4 between rounds (staying within the same heterogenous/homogenous treatment and majority/minority status). This is like having a larger community, where individuals may be less sure how to interpret each other's behaviour.

In the -Het variant of all these treatments, groups had a single participant with a minority colour label, just as in PX-Het.

Result 11. *In PX-Hist-Het and PX-Stranger-Het treatments, minorities were significantly more likely to be targeted than majorities.*

	PX-Hist-Het	PX-Noise-Het	PX-Stranger-Het
Majority	0.02	0.05	0.07
Minority	0.22	0.07	0.20
p	< 0.05	0.86	< 0.001

Table 5: Expropriation rates in 3 heterogenous treatments. PX-Hist-Het treatment, rounds 11-20 only.

Table 5 shows expropriation rates of minority and majority individuals in the PX-Hist-Het, PX-Noise-Het and PX-Stranger-Het treatments, with p values for differences between them (from paired Wilcoxon tests at group level, or session/treatment level for Stranger treatments). In PX-Hist treatments we only use rounds 11-20. If we break expropriation

[13] See Footnote 9.

down by contribution levels, then as in treatment PX, only lowest contributors were targeted. However, unlike in treatment PX, in PX-Hist and PX-Stranger treatments minorities were more likely to be targeted than majorities even among *unique* lowest contributors.[14]

Result 12. *In PX-Hist-Het and PX-Noise-Het treatments, minorities increased their contributions less than majorities after being expropriated.*

Columns 2-4 of Table 4 report regressions of contributions for PX-Hist-Het, PX-Noise-Het and PX-Stranger-Het treatments. As in treatment PX-Het, majority subjects increased their contribution after being targeted by two group members or expropriated by three group members. However, minority subjects increased their contributions less, or not at all: the interaction of *Targeters* with minority status is generally negative, and significant in PX-Hist-Het and PX-Noise-Het treatments.[15]

These treatments show that under "difficult" circumstances (a history of differential treatment, or imperfectly visible contributions to a public good), minorities were targeted more than majorities, and reacted differently, increasing their contributions to the public good less after being targeted or expropriated. This could be because they expected to be expropriated irrespective of their contribution level, or because they resented being targeted unfairly. These mechanisms did not lead to significant unconditional differences in contributions between homogenous and heterogenous treatments, so it could be argued that they are not having a strong impact.[16] However, the high variance in contributions within treatments lowers our power to detect differences here. Also, our group manipulation was very minimal: nothing more than randomly assigned color labels.

6 Conclusion

Punishing free-riders need not always be costly. It can be profitable – even too profitable. Existing theory conceptualizes social order as preventing individual free-riding, and downplays the simultaneous problem of controlling expropriation by groups. The two issues are related in complex ways, and social order involves a delicate balance between them. As our experiment shows, if technology or social institutions make expropriation easy, this can harm rather than help public good provision, and can lead to deadweight costs of its own.

Rethinking the theory of public good provision suggests a new explanation for the problems of heterogenous communities. The history of the California Gold Rush shows

[14]See Appendix 3.

[15]See footnote 9.

[16]Details are reported in the appendix.

that “punishment of free-riders” (or “expropriation of minorities”) can spark conflict. Our experiments imposed a minimal form of heterogeneity: different, randomly assigned, public color labels. Nevertheless, majority groups used this as a coordination device for expropriation. In some treatments, minorities reacted to expropriation differently from majority group members, refusing to increase their contributions.

Our argument’s policy implications with regard to heterogeneity are, in one sense, pessimistic. “Nation-building” is often proposed as a solution to ethnic tensions (Miguel, 2004). However, if even minimal differences between groups can cause problems, nation-building must wholly erase these differences to succeed, which is difficult. The same is true of integration policies for ethnic minorities in developed societies. An alternative approach is to create institutions that reduce ambiguity and legitimize the punishment of free-riders. In our experiments, minorities only reacted differently to punishment when a history of previous expropriation, or an ambiguous situation, made it hard to know the reason for being punished. When contributions were common knowledge, they contributed more after being expropriated, just as majority group members did. In the real world, liberal institutions such as trials with due process may reassure all groups that they are being treated fairly, while intergroup communication can defuse conflict by squashing rumors and misperceptions (Easterly, 2001*a*; Varshney, 2003).

A large literature, including important work on costly punishment and on cooperation in repeated games, has grown from the assumption that sanctioning is an under-supplied public good. We have argued that this assumption needs rethinking. We hope that doing so will lead to new lines of research. Important topics include: how state institutions can emerge from decentralized expropriation; the link between expropriation and intergroup conflict; and how expropriative punishment is perceived by different groups in heterogeneous societies.

Appendix 1: Proofs

Equilibria in the expropriation subgame when $k > 0$: rational play

If $k > (f - l)/M > 0$, then targeting always costs more than it can earn.

If $M = 1$, then, unless everybody is being targeted by exactly one player, some player j is not being targeted, and another player who is in a expropriating group of two or more, or who is not in any expropriating group, could profitably deviate to targeting j.

If $M > 1$, three conditions define an equilibrium: players targeting no-one ($x_i = 0$) must weakly prefer not to target anyone; players targeting someone ($x_i > 0$) must weakly prefer not to play $x_i = 0$; and they must also weakly prefer not to change targets. The first condition implies that if any player is not targeting somebody, then either nobody is successfully expropriated, or anyone who is targeted is targeted by $\overline{T} = N - 1$ players, so that, by (4), joining and increasing the size of the expropriating group would cost more than it gained. The second condition implies that if any player is targeting somebody, they are in an expropriating group of at least size M, so that expropriation succeeds. The third condition implies that all successful expropriating groups differ by at most one in size, otherwise a player in the larger expropriating group could increase their payoff by switching to the smaller one.

Thus, there are two kinds of equilibria: those where some players do not target anyone and all successful expropriating groups are of size $\overline{T}$; and those where everybody targets someone successfully, and all expropriating groups are of the same size plus or minus one. The second kind requires at least two targets, since nobody prefers to target themselves, and this requires $M \leq N/2$.

Equilibria when $k = 0$

The proof follows the same lines as for the case $k > 0$. The maximum profitable expropriating group size is $\bar{T} = N - 1$. If anyone is in an expropriating group of size $M - 1$ then another player would be able to join and achieve the highest possible payoff. (Note that $M - 1 \leq N - 2$ so there is always a player outside the expropriating group who is not being targeted by it.)

Boundedly rational play in the expropriation subgame

Suppose that individuals make mistakes in their targeting: if individual i targets individual j, with some probability, $\gamma \in (0, 1/2)$, the targeting will fail and be directed instead towards a randomly chosen individual, with an equal probability $\gamma/(N-1)$ for each. This could happen because of semantic ambiguity in the identity of the targets (as in Crawford and Haller, 1990): if there are multiple symmetric targets and there is no clear label that identifies them, coordination requires a "common language" that makes it possible for players to uniquely identify each other's strategies.[17]

Then if an individual i conjectures that another $T^j - 1$ individuals are targeting the same individual j,the expected payoff to an individual from targeting the same individual,

[17]Such "equilibria with trembles" can be rationalized by reference to a game of incomplete information, where players can be one of two types, either rational players that best respond to other players, or automatons that simply randomize across targets. Then, given a known fraction of automatons in the population, the conditions $EU(x_i = j \mid M, \overline{T}, \gamma) \geq 0$ correspond to a perfect Bayesian equilibrium of the incomplete information game.

j, is

$$\sum_{T=M}^{N} \Pr(T^j - 1 = T - 1 \mid \gamma)\ \frac{f-l}{T} - k \equiv \mathrm{EU}(x_i = j \mid M, T^j, \gamma), \tag{8}$$

where $\Pr(T^j - 1 = T - 1 \mid \gamma)$ is the probability that j will be *actually* targeted by $T-1$ individuals other than i.

As M increases, it should be harder to target anybody in equilibrium: a group with more members is more likely to suffer coordination failures, and this lowers the expected payoff in (8). Below we prove this for the case where N is large, as well as for the case $N = 4$ (as in our experiment). Thus, when minimum group size is larger, sustaining coordination requires a lower individual probability of mistakes.

When the second-stage is combined with a first-stage contribution game, actions in the first stage can guide coordination choices in the second stage. In the experimental literature on coordination games (e.g. Crawford, Gneezy and Rottenstreich, 2008), indeterminacy in coordination games can be resolved by payoff-irrelevant aspects that are salient to subjects (such as departures from symmetry). Here, contributions to the public good can play this role; i.e. being the lowest contributor can act as an observable marker that makes an individual salient and reduces semantic ambiguity, lowering γ from γ_0 to $\gamma_D < \gamma_0$ when targeting that individual. Then for some parameter values, expropriation will be viable only when the target is a unique lowest contributor. There will be equilibria where defectors are expropriated off the equilibrium path of play, but no equilibria where non-defectors are expropriated. In particular, if M is low so that $\gamma_0 < \bar{\gamma}$, then all equilibria will survive; if M is such that $\gamma_D < \bar{\gamma} < \gamma_0$, then only defectors can be expropriated in equilibrium; if M is so high that $\bar{\gamma} < \gamma_D$, then expropriation is never possible. Thus, there is a "sweet spot" where coordination is easy enough to expropriate defectors, but not so easy that non-defectors can be expropriated.

To illustrate, suppose $N = 4$ and $(f-l)/k = 4$. For $M = 3$, in the expropriation subgame, there is no equilibrium with expropriation when $\gamma = \gamma_0 = 1/5$, but there is an equilibrium with expropriation for for $\gamma = \gamma_D = 1/10$. Thus, in the whole game, there are equilibria where positive contributions are supported by off-the-equilibrium-path threats, but there are no equilibria featuring inefficient expropriation. (There are still "coordination failure" equilibria where contributions are zero and nobody is expropriated.) If $M = 1$ then the only equilibrium involves expropriation of all players, for both values of γ, and therefore in the whole game contributions are zero and the outcome is the most inefficient one.

Equilibria in the expropriation subgame: boundedly rational play with N large

Consider a candidate equilibrium where an individual j is targeted by a group of size $R \geq M$, and that there are Q other individuals who are targeting individuals other than j; $N-R-Q$ individuals are targeting nobody. For somebody in the targeting group (R) considering the choice of target, the probability that exactly X individuals *actually* target j is then

$$\sum_{z=0}^{X} \binom{R}{z} (1-\gamma)^z \gamma^{R-z} \binom{Q}{X-z} \left(\frac{\gamma}{N}\right)^{X-z} \left(1-\frac{\gamma}{N}\right)^{Q-(X-z)}.$$

If N is large, the terms of this sum approach zero for all z except for $z = X$, and the expression approaches

$$\binom{R}{X} (1-\gamma)^X \gamma^{R-X}. \tag{9}$$

Then, the expected utility of a player targeting j approaches the sum of (9), over all values of X between M and R:

$$EU(R) \equiv -k + \sum_{X=M}^{R} \binom{R}{X} (1-\gamma)^X \gamma^{R-X} \frac{f-l}{X}. \tag{10}$$

For an equilibrium in which somebody is targeted, it is necessary and sufficient that this expected utility is positive for all R. Note that the above approximation does not depend on Q. Thus, if the above is positive (negative) for some R, then for all sufficiently large N there will (will not) be an equilibrium in which a single group of size R targets a player.

The condition for the existence of any equilibrium in which someone is targeted is therefore that (10) is positive for some R:

$$\begin{aligned} \overline{EU} &\equiv \max_{R \in \{M,\ldots,N-1\}} EU(R) \\ &= \max_{R \in \{M,\ldots,N-1\}} -k + \sum_{X=M}^{R} \binom{R}{X} (1-\gamma)^X \gamma^{R-X} \frac{f-l}{X} \geq 0. \end{aligned} \tag{11}$$

We now show that $\overline{EU}$ is decreasing in γ. Thus, $\overline{EU}$ will be non-negative for $\gamma \leq \bar{\gamma}$, where $\bar{\gamma}$ solves (11) with equality. Because $\overline{EU}$ is also strictly decreasing in M (since this shrinks the set of possible expropriating group sizes R and of "achieved" group sizes X), when M increases $\bar{\gamma}$ will be lower.

The proof has two parts:

1. $EU(M)$ is strictly decreasing in γ. This can be seen by setting $R = M$ in (10).

2. For any value of R and γ, if $EU(R)$ is weakly (strictly) increasing in γ, then $EU(R-1)$ is weakly (strictly) greater than $EU(R)$.

Putting these two together, if R' is such that $EU(R') = \max_{R\in\{M,\dots,N-1\}} EU(R)$, then $EU(R') = \overline{EU}$ must be constant or decreasing in γ. Therefore, $\overline{EU}$ itself is decreasing in γ everywhere.

To prove point 2, first compute $\Delta EU(R) \equiv EU(R-1) - EU(R)$:

$$\begin{aligned}\Delta EU(R) &= \sum_{X=M}^{R-1} (1-\gamma)^X \gamma^{R-1-X} \frac{f-l}{X}\left(\binom{R-1}{X} - \gamma\binom{R}{X}\right) - (1-\gamma)^R \frac{f-l}{R} \\ &= \sum_{X=M}^{R-1} \binom{R}{X} \frac{f-l}{X}(1-\gamma)^X \gamma^{R-X-1}\left(\frac{R-X}{R} - \gamma\right) - (1-\gamma)^R \frac{f-l}{R},\end{aligned}$$

where the second line uses that $\binom{R-1}{X} = (1-X/R)\binom{R}{X}$. This is positive if and only if

$$\sum_{X=M}^{R-1} \binom{R}{X} \frac{f-l}{X}(1-\gamma)^X \gamma^{R-X-1}\left(1 - \frac{X}{R} - \gamma\right) > (1-\gamma)^R \frac{f-l}{R}. \tag{12}$$

Next, differentiate $EU(R)$ by γ to give:

$$\begin{aligned}&\sum_{X=M}^{R} \binom{R}{X} \frac{f-l}{X}\left((1-\gamma)^X (R-X)\gamma^{R-X-1} - X(1-\gamma)^{X-1}\gamma^{R-X}\right) \\ &= \sum_{X=M}^{R-1} \binom{R}{X} \frac{f-l}{X}(1-\gamma)^{X-1}\gamma^{R-X-1}((1-\gamma)R - X) - \frac{f-l}{R}(1-\gamma)^{R-1}R.\end{aligned}$$

This is positive if and only if

$$\sum_{X=M}^{R-1} \binom{R}{X} \frac{f-l}{X}(1-\gamma)^{X-1}\gamma^{R-X-1}((1-\gamma)R - X) > \frac{f-l}{R}(1-\gamma)^{R-1}R.$$

Multiplying both sides by $(1-\gamma)/R$ gives the same inequality as (12).

Equilibria in the expropriation subgame: boundedly rational play with $N = 4$

We compare the cases $M = 1$ and $M = 3$. Define $\rho = (f-l)/k$. When $M = 1$, the expected payoff for a player from targeting another individual, assuming that all other individuals choose a different target, is[18]

$$EU\Big(x_i = j \mid M = 1, T^j = 1, \gamma\Big) = (f - l)\left((1-\gamma)^2 + 2\,\frac{(\gamma/2)(1-\gamma)}{2} + \frac{(\gamma/2)^2}{3}\right) - k. \quad (13)$$

This is less than unity and is decreasing in γ. For $\rho < 1$, (13) is always negative, and for $\rho > 1$ it is non-negative if $\gamma < 9/7 - \Big((84 - 3\rho)/\rho\Big)^{1/2}/7 \equiv \gamma'$. For $M = 3$, the expected payoff for a player from targeting another individual, assuming that two other individuals also choose the same target, is

$$EU(x_i = j \mid M = 3, T^j = 3, \gamma) = (f - l)\,\frac{(1-\gamma)^2}{3} - k, \quad (14)$$

which is decreasing in γ. For $\rho < 3$, (14) is always negative, and for $\rho > 3$ it is non-negative if $\gamma < 1 - (3/\rho)^{1/2} \equiv \gamma'' < \gamma'$. Thus, for $\rho > 3$, the maximum level of γ for which expropriation is profitable with $M = 3$ is smaller than the corresponding level with $M = 1$. Moreover, the negative effect of an increase in γ on the expected payoff from targeting is comparatively stronger for $M = 3$ than for $M = 1$: the ratio of the gross expected payoffs (gross of k) for $M = 1$ and $M = 3$ is increasing in γ. So, bounded rationality makes the coordination problem comparatively "more difficult" in the case $M = 3$ than it does in the case $M = 1$.[19]

Appendix 2: Experiment chronology

We ran three sets of sessions (in chronological order):

Set 1 This implemented treatments PX, P and X, along with PX-Het, P-Het and X-Het. The "institution" treatments (P, X, PX) were varied between sessions and were also crossed with within-session treatments manipulating group heterogeneity (PX vs. PX-Het etc.)

Set 2 This implemented treatments PX-History, PX-Noise and PX-Stranger, as well as PX-History-Het, PX-Noise-Het and PX-Stranger-Het. The History, Noise

[18] The first term in brackets is the probability that i is the only individual actually to target j; the second term is the probability that an individual other than i is mistakenly targeting j even when the supposed target was $j' \neq j$, divided by two (the number of expropriators sharing the amount that is expropriated); the third term is the probability that two other individuals mistakenly target j, divided by three (the number of expropriators sharing the amount that is expropriated).

[19] The case $M = 2$ introduces the possibility of equilibria where individuals are targeted by two individuals as well as equilibria where one individual is targeted by three other individuals, depending on the values ρ and γ. A full theoretical characterization is possible but tedious, and does not add anything of substance to the insights we can gain by comparing the cases $M = 1$ and $M = 3$. In our laboratory experiments, we include treatments with $M = 2$, as well as treatments with $M = 1$ and $M = 3$.

and Stranger treatments were per-session and were crossed with within-session treatments manipulating group heterogeneity (PX-History vs. PX-History-Het etc.)

Set 3 This implemented treatments PX-M1, PX-M2 and PX-M3. Treatments were balanced across groups within sessions.

Appendix 3: Additional results

Figure 4 shows expropriation by contribution status, for treatments PX-Hist-Het, PX-Noise-Het and PX-Stranger-Het . Table 6 shows logit regressions where the dependent variable is being expropriated, for treatments PX, PX-Hist, PX-Noise, PX-Stranger, combined with their -Het variants. Non-lowest contributors are excluded, since they were almost never expropriated (hence, N is lower than for Table 4).

	PX	PX-Hist	PX-Noise	PX-Stranger
Intercept	-2.60^{***}	-3.08^{***}	-2.01^{***}	-2.90^{***}
	(0.36)	(0.49)	(0.39)	(0.56)
Minority	2.28^{***}	3.89^{***}	2.69	2.35^{***}
	(0.55)	(1.01)	(1.79)	(0.60)
-Het treatment	-1.07	-0.70	-1.60	-0.12
	(0.55)	(1.06)	(1.26)	(0.69)
Unique lowest	2.94^{***}	1.53^{***}	0.86	2.47^{***}
	(0.43)	(0.34)	(0.49)	(0.51)
Minority * unique lowest	-2.72^{***}	-2.17	-9.03^{***}	-1.63^{**}
	(0.78)	(1.12)	(1.78)	(0.56)
-Het * unique lowest	0.47	0.31	1.17	0.06
	(0.65)	(1.24)	(1.31)	(0.70)
Num. obs.	805	322	326	912
Pseudo R^2	0.35	0.27	0.08	0.24
L.R.	230.83	52.21	16.08	168.25

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Robust s.e.s clustered by group/matching group. Non-lowest contributors excluded.

Table 6: Logit regressions: logged odds of being expropriated

In Experiment 1 treatments, the coefficient on *Minority* is significant, but the summed coefficient *Minority + Minority * Unique lowest* is not. Thus, minorities were only targeted more when they were one of two or three equal lowest contributors in the group. In Experiment 2, summed coefficients *Minority + Minority * Unique lowest* are significantly positive in history and stranger sessions ($p < 0.1$ and $p < 0.05$ respectively), significantly negative in noise sessions.

The decision to contribute is not exogenous. We check robustness by adding further independent variables. Table 7 repeats the regressions, adding the individual's contri-

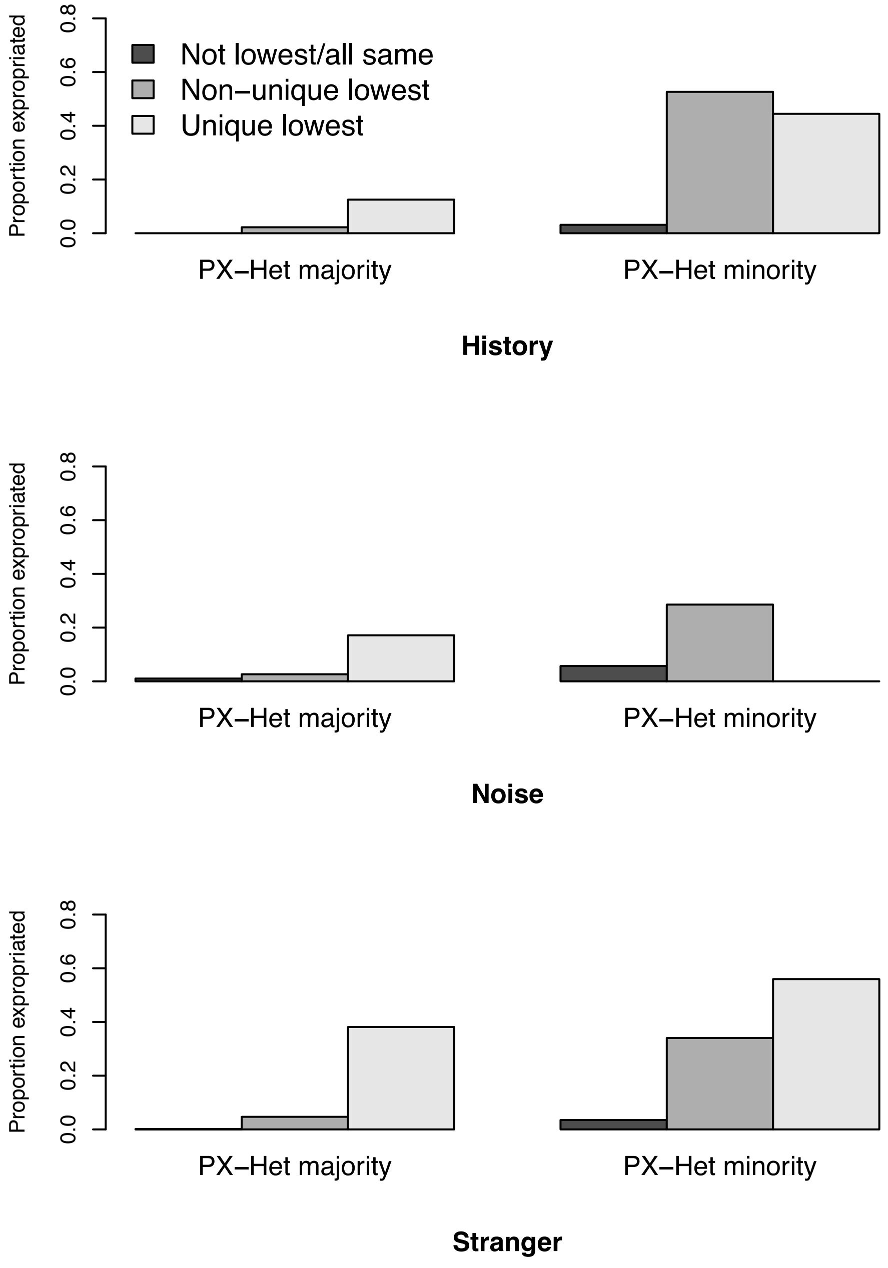

Figure 4: Proportion expropriated by minority status and contribution, treatments PX-Hist-Het, PX-Noise-Het, PX-Stranger-Het

bution, and whether they were expropriated in the previous round. These variables are significant, but it remains true that unique lowest contributors and minorities are targeted.

Table 8 reports mean contributions for PX-History, -Noise and -Stranger treatments and their -Het variants.

	PX	PX-Hist	PX-Noise	PX-Stranger
Intercept	-3.66^{***}	-3.42^{***}	-2.09^{***}	-3.01^{***}
	(0.55)	(0.45)	(0.39)	(0.61)
Minority	2.47^{***}	2.89^{**}	2.49	2.24^{***}
	(0.58)	(1.04)	(1.66)	(0.61)
-Het treatment	-0.91	-0.51	-1.56	-0.10
	(0.57)	(1.05)	(1.21)	(0.68)
Unique lowest	3.23^{***}	1.10^{**}	0.77	2.48^{***}
	(0.52)	(0.36)	(0.51)	(0.54)
Contribution	0.04^{***}	0.05^{*}	0.00	0.00
	(0.01)	(0.02)	(0.01)	(0.02)
Lag exprop.	1.18^{***}	2.48^{***}	0.66	0.81^{***}
	(0.31)	(0.55)	(0.41)	(0.24)
Minority * unique lowest	-2.69^{***}	-1.48	-8.79^{***}	-1.60^{**}
	(0.78)	(1.25)	(1.65)	(0.54)
-Het * unique lowest	0.41	0.15	1.23	0.04
	(0.68)	(1.28)	(1.31)	(0.70)
Num. obs.	805	322	326	912
Pseudo R^2	0.42	0.41	0.09	0.26
L.R.	277.60	81.37	18.38	180.62

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Robust s.e.s clustered by group/matching group. Non-lowest contributors excluded.

Table 7: Logit regressions: logged odds of being expropriated, extra controls

	PX-Hist	PX-Noise	PX-Stranger
Homogenous	9.75	17.39	16.22
Heterogenous	14.14	17.38	15.08
Mann-Whitney p	0.24	0.52	0.93

Table 8: Contributions by treatment

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