Inequality and conflict outbreak*

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Abstract

We model conflict as a multi-prize contest which takes place if a minimum number of players (which we interpret as social classes) reject the status-quo prize distribution. In the event of conflict, the status-quo prizes are reshuffled across players depending on their efforts. We first show that, for a broad family of contest models, equilibrium rent dissipation takes the form of a Generalized Gini coefficient of the prize distribution (also tackling the well-known issue of existence of an equilibrium). Secondly, we show that conflict occurs when inequality is low and deprivation (a concept that we define) is high, where these measures are computed with respect to the prize distribution. Thirdly, we find empirical evidence that supports our predictions using an unbalanced panel of 41 high and middle income countries, taking the number of labor strikes per capita as a proxy for the occurrence of conflict and measuring inequality and deprivation with respect to the income distribution.

Keywords: conflict; inequality; Gini coefficient; deprivation.
JEL classification: C70; D72.

1 Introduction

What is the relation between the endowment and distribution of scarce resources and the welfare of the population that controls them? And more specifically, what is the relation between the inequality of this distribution and the degree of conflictual activities

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within this population? This is a fundamental question in economics and other social sciences which can be tackled from many different perspectives given the complexity of the problem.[1] In this paper we study the relation between conflict and the inequality of the contested resources in a multi-prize contest model, identifying a link between conflict intensity and the Gini coefficient of the prize distribution. Although it may seem obvious that a significant increase in the inequality of contested resources should lead to higher conflict intensity to obtain them, it is not at all clear what constitutes a 'significant inequality increase' in this context. The employment of inequality majorization criteria (e.g., the Pigou-Dalton transfer principle) is hardly questionable, but it leaves the analysis incomplete as many resource distributions remain non-comparable.[2] Moreover, the relation between inequality and conflict outbreak is largely unexplored, an issue that we address both theoretically and empirically. Roughly speaking, in this paper we argue that conflict is less likely to occur when the inequality of the contested resources is high, because players expect the corresponding conflict to be very intense and costly (as they have a lot to win and to lose) and therefore refrain from initiating it.

We start by analyzing the incentives to exert costly effort in an ongoing conflict (we consider the incentives to initiate such conflict later on) which we model as a contest for multiple commonly valued prizes. These prizes can be interpreted as quantifiable rents attached to the structural roles of a society, where by structural roles we mean the key figures which are intrinsic to the organization of the society as defined by, e.g., the means of production.[3] Then, one could think of contestants (or players) as economic classes while abstracting from the collective action problem within each class.[4] For simplicity we assume that players are risk neutral, that their effort costs are sunk and linear, and that their payoffs are symmetric in the ongoing conflict.[5] For a broad class of contest models, we identify a linear relation between equilibrium rent dissipation (i.e., the fraction of the total value of prizes that is wasted in aggregate equilibrium efforts, which is a well-known proxy for the intensity of conflict) and the inequality of the prize distribution as measured by the class of Generalized Gini coefficients put forward in Donaldson and Weymark (1980) and Weymark (1981). Roughly speaking, the intensity of conflict is proportional to this particular class of inequality indices because, being linear in each prize's share of the total value, we can think of them as weighted averages of distances between pairs of prizes that

[1]See, e.g., Benabou (1996); Acemoglu and Robinson (2000); Sachs and Warner (2001); Esteban and Ray (2008a).

[2]To see an example, consider three ways of distributing a unit of resources among three individuals: $a = (1, 0, 0), b = (.7, .3, 0), c = (.8, .1, .1)$. While distribution a is unquestionably more unequal than b and c (i.e., both b and c can be derived from a by a sequence of Pigou-Dalton transfers, that is, transfers from rich to poor that do not change the ranking of resources), it is not immediately clear whether b is more or less unequal than c.

[3]The underlying assumption is that, due to indivisibilities, (a substantial part of) these rents cannot be shared but only 'conquered'. This is in line with the idea that the hierarchical structures of a society are highly resilient to social change. Roughly speaking, revolutions do not change the fact that a restricted elite exercises coercion and privilege by controlling the means of production, but only the identity of such elite. In sociology, related views are put forward in Elite Theory.

[4]We show in an extension that, roughly speaking, the different sizes of such classes do not affect their incentives in conflict if the chosen effort of each class is supported by a majority of class members.

[5]The symmetry restriction is relaxed in an extension where we allow for heterogeneous head-starts.

capture the incentives to climb the social ladder.

To sharpen our predictions on conflict intensity we focus on the pair-swap contest model introduced in Vesperoni (2016), which defines a convenient functional form for the mapping from efforts to the probabilities of rankings of players. Our crucial results are that, in a symmetric equilibrium of the pair-swap model, rent dissipation is a linear function of the standard Gini coefficient of the prize distribution, and that this equilibrium exists for any possible prize distribution under a basic parameter restriction on the conflict technology. Note that previous approaches in the literature required restrictions on the prize distribution to obtain existence, while achieving a result free of such restrictions is crucial to properly assess the effects of inequality on conflict.[6] Clark and Riis (1998) and Fu et al. (2014) analyze similar frameworks for the ongoing conflict but they employ different functional forms for the probabilities of allocations, respectively known as the best-shot and the worst-shot models.[7] While none of these contributions explicitly focuses on the relation between conflict and inequality, we show that equilibrium rent dissipation takes the form of a Generalized Gini coefficient also for the best-shot and worst-shot models, although not among the widely known in the literature.

Having established equilibrium behavior in an ongoing conflict, understanding conflict outbreak is straightforward. We assume that, by an exogenous rule, the status-quo is challenged if and only if at least k players strictly prefer conflict to peace. Depending on this, a conflict consisting in the aforementioned contest to reshuffle the status-quo prizes may or may not take place in the second stage.[8] In this basic setup, we find that in a subgame perfect equilibrium peace is sustained if and only if the inequality of the prize distribution (which coincides with the expected equilibrium rent dissipation) is sufficiently larger than what we call the deprivation of the k^{th}-poorest player (a measure of the deviation of the k^{th}-lowest prize from the mean).[9] Intuitively, high inequality indicates that a large fraction of the total value is wasted in case of conflict outbreak, as players fight hard having much to win and to lose. On the other hand, a player with high deprivation is inclined to initiate conflict as her status-quo prize is much lower than the expected prize from conflict (which is equal to the mean prize), where the focus on the k^{th}-poorest player is due to deprivation being monotonic in the status-quo prize. So, high inequality decreases the chances of conflict, high deprivation increases them, and the interaction of these two terms determines conflict outbreak.

Before moving to the empirics, we consider a few robustness checks on the theory. So far we have assumed that players' payoffs are perfectly symmetric in the occurrence of conflict. In a basic extension of our model we consider asymmetries between players

[6]See, e.g., Clark and Riis (1998); Schweinzer and Segev (2012); Akerlof and Holden (2012); Fu et al. (2014). One relevant exception is the recent working paper by Drugov and Ryvkin (2017).

[7]The best-shot model is originally introduced in Clark and Riis (1996), while the worst-shot model in Fu et al. (2014). Both the best-shot and the worst-shot models belong to the general class of contests with multiple prizes introduced in Nalebuff and Stiglitz (1983) and Green and Stokey (1983).

[8]In an extension we allow the status-quo prizes to be partially destroyed in the occurrence of conflict.

[9]For related approaches to deprivation, see Paul (1991), Bossert and D'Ambrosio (2006) and references therein.

in terms of heterogeneous head-starts, i.e., fixed amounts of pre-committed efforts that are added to players' efforts without affecting (current) costs. In this setting, it seems natural to assume that a player's head-start is proportional to her status-quo prize, since it can be interpreted as a player's investment in self-protection in a pre-game stage. We show that our previous analysis directly extends if this proportionality is governed by a linear function. In addition, we prove that our core results persist if we let a fraction of each status-quo prize to be destroyed in the occurrence of conflict (thus allowing for inefficiencies of conflict outbreak that go beyond effort exertion), as long as this fraction is a linear function of the value of each status-quo prize. Note that these linear functions can be either increasing or decreasing, thus capturing a wide range of effects. Finally, we provide an explicit representation of players as social classes of heterogeneous size where each class takes a collective decision on its level of effort in conflict. In this setting, we show that all our results persist if, roughly speaking, within each class the benefits are symmetrically distributed around the mean while the costs are equally shared, and each class implements the effort level that is preferred by a majority of class members to any alternative (i.e., that is a Condorcet winner). We wish to remark that these are far from general treatments of these topics, but rather examples to show that our results are robust to these extensions under certain conditions.

In our empirical section, we evaluate the predictions of our model using a panel dataset of 41 high and middle income countries between 1980 and 2015. The data we assemble contains observations for inequality and deprivation characteristics of the income distribution in each country and year, which we take as proxies for their counterparts in the prize distribution, and the number of labor strikes per capita in each country and year, which we take as a proxy for conflict outbreak, along with control variables per-capita income, population size, unemployment rate and manufacturing share in GDP. We follow two estimation procedures: ordinary and instrumental variable fixed-effects models. The purpose of the latter is to allow for a possible endogeneity between income inequality and the number of labor strikes per capita due to reverse causality (i.e., labor strikes leading to redistribution of income). For the instrumental variable estimation, we take the current and lagged yearly oil or coal prices as instruments for income inequality, relying on the role of these prices in changing the relative costs of labor and capital and therefore the relative retribution of these factors of production. Intuitively, as these are internationally traded commodities their prices should be independent of the occurrence of labor strikes within each country, and therefore immune to reverse causality. All our estimation results support our hypotheses. In particular, we find that income inequality has a statistically significant and negative effect on the occurrence of labor strikes. The estimated coefficients for deprivation are systematically positive, thus in accord with our hypothesis, although their statistical significance is weaker.

The paper proceeds as follows. In Section 2 we review the literature, in Section 3 we present our model, in Section 3.1 we derive the equilibrium results on the determinants of conflict outbreak, in Section 3.2 we study the three theoretical extensions, in Section 4 we provide the empirical evidence for our theoretical predictions, and we conclude with Section 5. All proofs are in Appendix.

2 Related literature

We start this section by reviewing the narrow body of literature that links models of conflict, and more specifically contests, to the measurement of inequality and related concepts. We refer to Konrad (2009) and Chakravarty (2015) for a broader take on these topics. We then review a number of empirical contributions on the determinants of conflict outbreak. As this literature is vast, we focus primarily on the determinants of labor strikes and we refer to Garfinkel and Skaperdas (2012) for a more comprehensive discussion on different forms of conflict such as civil war and terrorism. To locate our contribution within this literature, it is useful to acknowledge that it is loosely inspired by Esteban and Ray (1999, 2011), which develop a contest model where equilibrium efforts are a function of the polarization index introduced and axiomatically characterized in Esteban and Ray (1994). In their contest model there is always a unique winner and the payoff of a losing player depends on the identity of the winner.[10] Their single-winner framework is designed to represent an ongoing conflict between ethnic groups in a society where the winning group decides on the nature of a public good, indirectly favoring groups with similar preferences. In their model, an aggregation of the distances between the preferences of winners and losers determines the degree of polarization. Compared to them, we take a more materialistic approach as in our common-value multi-prize framework we interpret prizes as material resources attached to structural roles in a society.

There are other papers that explore the relation between conflict and inequality from a materialistic view point. Cubel and Sanchez-Pages (2014) analyze equilibrium behavior in a contest between coalitions (or groups) of players, identifying a link between the inequality of the distribution of resources within groups and their relative win probabilities via a free-riding effect. The functional form they employ to represent win probabilities belongs to the class axiomatically characterized in Münster (2009), and the measure of inequality that links to their model is the well-known Atkinson index. As their focus is on how the inequality of resources within groups affects the relative strength of groups in a single-winner conflict across them, they look at the effects of inequality on conflict from a completely different perspective than ours. Hopkins and Kornienko (2010) develop a conflict model where players allocate their endowments between consumption and effort, where the latter increases the chances of winning a better prize and has also intrinsic value.[11] They analyze the effects of inequality in the opportunity cost of effort (which is inversely proportional to endowment) and inequality in prize values, finding that inequality of prizes tends to affect equilibrium efforts positively while the opposite holds for inequality of opportunity costs. Conversely, in this paper we abstract from inequality of opportunity costs assuming they are symmetric.[12] On the other hand, while

[10] Klose and Kovenock (2015a,b) analyze an all-pay auction with identity-dependent externalities along the lines of Esteban and Ray (1999, 2011).

[11] Closely related frameworks are analyzed in Hopkins and Kornienko (2004, 2006, 2009). Other related papers on contests for status are Moldovanu et al. (2007), Besley and Ghatak (2008) and Auriol and Renault (2008).

[12] It is well-known that in single-prize contests inequality of opportunity (or marginal) costs lowers equilibrium efforts. We expect an analogous effect in our setup, although a general analysis with arbitrary

they approach inequality in terms of majorization criteria (e.g., stochastic dominance), in this paper we focus on the microfoundation of inequality measures that provide complete orderings of distributions of resources based on the intensity of conflict they induce. Another related paper that takes a materialistic approach is Andonie et al. (2014), which provides a microfoundation for inequality measures of the Generalized Entropy family via a conflict model. They consider a conflict game where each player can claim a prize from a set of commonly valued prizes of different value and prizes are allocated only if there are no conflictual claims. They focus on symmetric mixed strategy equilibria showing that the probability of conflictual claims increases with the inequality of prize values. Hence, like in our setup, the higher the inequality of the prize distribution the higher the conflict loss. In an extension, they also analyze a contest model closer to our setup and discuss equilibrium effort in relation to inequality of prizes, focusing on identifying conditions such that equilibrium effort satisfies the Pigou-Dalton transfer principle. They also show that a particular contest model from this class leads to equilibrium efforts proportional to the standard Gini coefficient, where one key difference from our approach is that they assume the marginal cost of effort to depend on the sum of prizes.[13]

Until now we focused on the literature on the intensity of ongoing conflicts. We now briefly address the literature on conflict outbreak. Esteban and Ray (2008b) extend the aforementioned model in Esteban and Ray (1999) to study determinants of conflict outbreak within their polarization framework. As we do, they identify a negative relation between conflict intensity and conflict outbreak, and they relate these variables to polarization and the institutions governing peace. More generally, the theoretical literature on conflict outbreak has focused on winner-take-all contests looking at the effects of dynamic incentives (e.g., Garfinkel and Skaperdas, 2000), transfers (e.g., Beviá and Corchón, 2010) and asymmetric information (e.g., Bester and Wärneryd, 2006; Corchón and Yıldızparlak, 2013). To the best of our knowledge, our paper is first in studying conflict outbreak in a multi-prize contest and in linking the analysis to inequality measurement. From an empirical perspective, a lot has been said on the relation between the distribution of resources and the presence of conflict. Stewart (2008) provides a comprehensive discussion on the effects on the occurrence and intensity of civil wars of unbalanced distributions of resources within and across ethnic groups. On this topic, recent empirical contributions are Gubler and Selway (2012), Huber and Mayoral (2016) and Guariso and Rogall (2017). Another relevant form of conflict that can be linked to the distribution of resources is terrorism. Recent empirical studies on the socio-economic determinants of terrorism are Caruso and Schneider (2011) and Freytag et al. (2011). More specifically on industrial conflict (i.e., labor strikes), which is the focus of our empirical contribution, there are strands of literature in economics and political science that emphasize different determinants for the outbreak and the intensity of strike activity. Empirically recognized determinants of strike activity are economic prosperity and the long-term business cycles (e.g., Rees, 1952;

prize structure is technically challenging and beyond the scope of this contribution.

[13]Also, to the best of our knowledge the contest model studied in Andonie et al. (2014) lacks stochastic and axiomatic foundations and it can be justified only in terms of a sequence of contests that progressively allocates the top prizes to the best performing players and excludes them from the following rounds, where the discriminative power of these contests decreases at each round according to a particular formula.

Ashenfelter and Johnson, 1969; McConnell, 1990), union concentration (e.g., Korpi and Shalev, 1979; Lindvall, 2013), and political composition of the parliament (e.g., Hibbs, 1978; Humphries, 1990). On the other hand, the theoretical literature on bargaining has explained labor strikes in terms of irrational behavior (e.g., Bishop, 1964) or asymmetric information (e.g., Hayes, 1984; Gary-Bobo and Jaaidane, 2014; Brunnschweiler et al., 2014). To our knowledge, our paper is first in establishing a theoretically and empirically consistent link between income inequality and industrial conflict. Finally, we contribute to this literature by providing a rationale for the declining trend in industrial conflicts observed in developed countries since the 1970s (see, e.g., Hamann et al., 2013), linking this phenomenon to the growing trend in income inequality in the same time period.

3 Theoretical model

There are $n \geq 3$ players in the population set $N := \{1, \ldots, n\}$.[14] Each player $i \in N$ is initially endowed with a prize that is commonly valued $v_i \geq 0$ by all players. Without loss of generality, we assume $v_i \geq v_{i+1}$ for all $i \in N \backslash \{n\}$, so that player 1 is endowed with (a prize that is commonly considered) the best prize, player 2 with the second-best prize and so on. We interchangeably use the notation v_l where $l \in N$ indicates the level (first, second, etc.) of the corresponding prize in this ranking of valuations. For simplicity we rule out the trivial case where all prizes have equal value, assuming $v_i \neq v_{i+1}$ for some $i \in N \backslash \{n\}$.

A prize distribution $v := (v_1, \ldots, v_n)$ is a vector of common valuations of these n prizes. Denoting by $V \subset \mathbb{R}^n_+$ the set of all prize distributions that satisfy the aforementioned conditions, for each $v \in V$ we define its total value by $T(v) := \sum_{l \in N} v_l$ and its level of inequality by any index from the class of generalized Gini coefficient in relative form,[15]

$$I(v) := \frac{\sum_{l \in N} a_l v_l}{T(v)/n}, \tag{1}$$

where the parameters $a_1, \ldots, a_n$ constitute any non-increasing series that satisfies $\sum_{l=1}^{n} a_l = 0$ and $a_l \neq a_{l'}$ for some $l, l' \in N$. Within this class of inequality indices, the standard Gini coefficient

$$G(v) := \frac{2}{nT(v)} \sum_{l \in N} \left(\frac{n+1}{2} - l \right) v_l \tag{2}$$

corresponds to the series with $a_l = (n + 1 - 2l)/n^2$ for each $l \in N$.

In case of conflict outbreak, we model the ongoing conflict as a contest whose outcome is a ranking that determines the reshuffling of these prizes across players. We define a ranking as a mapping $r : N \to N$ which assigns a level to each player, where $r(i) = l$ means that player $i \in N$ is ranked at level $l \in N$ in ranking r. We assume that this

[14] While all our core results equally apply to the two-player case, we feel that the study of inequality requires at least three players to be meaningful.

[15] This class of indices has been introduced by Donaldson and Weymark (1980) and Weymark (1981).

mapping is bijective, so that each player is assigned to a different level, and we denote by $\mathcal{R}$ the set of all rankings that satisfy these conditions. This set comprehends all possible outcomes of the contest, and the realization of outcome $r \in \mathcal{R}$ indicates that each player $i \in N$ receives the prize $v_{r(i)}$ that corresponds to her level $r(i)$. In the event of conflict each player $i \in N$ exerts an effort $x_i \geq 0$ to increase her chances to obtain a highly valued prize, where $x := (x_1, \ldots, x_n) \in X := \mathbb{R}^n_+$ denotes a profile of such efforts. We define the degree of rent dissipation associated with the prize distribution $v \in V$ and the effort profile $x \in X$ by

$$R(v, x) := \frac{\sum_{i \in N} x_i}{T(v)}, \tag{3}$$

which represents the share of total value that is wasted in the aggregate efforts. Following a well-established tradition in the rent seeking literature, we take rent dissipation as a proxy of the intensity of conflict.

In our stylized representation of conflict outbreak, we assume that the status-quo (which leaves the allocation of prizes unchanged) is maintained if and only if more than $n - k$ players prefer so, where we refer to k as the tipping point. To avoid trivial cases, we assume that conflict initiation does not require the approval of individuals who would never gain from conflict. As it will be clear later on (see Proposition 2), this is guaranteed by any tipping point $k \in N$ that satisfies $v_{n+1-k} \leq T(v)/n$, that is, the k^{th}-lowest prize takes value weakly below the mean.[16] In relation to this, we define the deprivation felt by the k^{th}-poorest player by

$$D(v, k) := 1 - \frac{v_{n+1-k}}{T(v)/n}, \tag{4}$$

which is a measure of the gap between the k^{th}-lowest prize and the mean of the prize distribution, which (as we will see) represents the expected value of each player's prize in the event of conflict outbreak.[17] Note that the deprivation coefficient decreases in v_{n+1-k} and, given our restrictions, it takes value in the unit interval.

We now define the conflict technology (i.e., the success function) and players' payoffs. We assume a success function $p : \mathcal{R} \times X \to [0, 1]$ assigns a probability to each ranking for each effort profile, where $p(r, x)$ denotes the probability that ranking $r \in \mathcal{R}$ is the outcome of the contest given the effort profile $x \in X$. We assume that p is twice-differentiable and satisfies the axioms of exhaustivity and anonymity, which are standard in the literature and, roughly speaking, require that the probabilities of rankings sum up to 1 and are independent of players' identities, respectively.[18] Finally, we assume that the expected payoff of player $i \in N$ in the event of conflict is

$$\pi_i(v, x) := \sum_{r \in \mathcal{R}} p(r, x) v_{r(i)} - x_i, \tag{5}$$

[16] We ignore the tie-breaking rule in this calculation (see below).

[17] We refer to Paul (1991), Bossert and D'Ambrosio (2006) and references therein for related approaches to the measurement of deprivation of an individual with respect to reference groups.

[18] For a formal definition and discussion of these axioms, see Vesperoni (2016).

while i's status-quo payoff is v_i. Thus, players are risk neutral and have symmetric linear effort costs. These restrictions are imposed for tractability and are common simplifications in the contest literature. As already mentioned, conflict takes place if and only if at least k players prefer so (i.e., the tipping point is reached). As a tie-breaking rule we assume that, if a player's status-quo payoff is equal to her expected payoff from conflict, she prefers the status-quo.[19] For simplicity we formalize the process of conflict initiation as voting, where each player can vote for conflict or for the status-quo, and the tipping point k functions as a qualified majority rule. We assume that players vote simultaneously in the first stage, and they simultaneously exert effort in the second stage (only) in the event of conflict.

3.1 Equilibrium analysis

In this section we solve for subgame perfect equilibrium in pure strategies using backward induction. Note that we have a subgame if and only if a set of k or more players vote for conflict. We exclusively focus on equilibria where players vote sincerely in the first stage, and in each subgame of the second stage, they exert symmetric positive efforts. For short, in what follows we refer to this solution concept as equilibrium, and we denote by $x^* \in X$ the profile of equilibrium efforts in each conflict subgame.

To start our analysis, suppose that there is a non-increasing series of real-valued coefficients $a_1, \ldots, a_n$ with $\sum_{l=1}^{n} a_l = 0$ and $a_l \neq a_{l'}$ for some $l, l' \in N$ such that, for each player $i \in N$ and level $l \in N$,

$$\sum_{r:r(i)=l} \partial p\left(r, (x_i, x^*_{\neg i})\right) / \partial x_i \big|_{x_i = x^*_i} = a_l / x^*_i, \tag{6}$$

where $x^*_{\neg i}$ is any vector of symmetric positive real numbers representing the equilibrium efforts of all players other than i, and x^*_i is equal to such efforts so that $x^* = (x^*_i, x^*_{\neg i})$. The core restriction here is that the series $a_1, \ldots, a_n$ is non-increasing, which means that a marginal increase in a player's effort always increases her chances to be ranked higher. Although somewhat convoluted, this condition is in fact a very natural property shared by many contest models. For instance, any success function defined by a ranking of perturbed log-transformed efforts $\ln(x_i) + \epsilon_i$ where ϵ_i is *iid* noise with increasing failure rate leads to (6). To see this, let $p(r, x) = \Pr\left(\ln(x_{r^{-1}(1)}) + \epsilon_{r^{-1}(1)} > \ldots > \ln(x_{r^{-1}(n)}) + \epsilon_{r^{-1}(n)}\right)$, which leads to (6) with

$$a_l = \binom{n-1}{l-1} \int_{\mathbb{R}} F'(e)^2 F(e)^{n-l-1} (1 - F(e))^{l-2} \left[n - l - (n-1)F(e)\right] de,$$

where $F : \mathbb{R} \to [0, 1]$ is the cumulative distribution function of each noise term.[20] In the literature there are three families of success functions in closed-form that satisfy (6):

[19] This restriction is purely to simplify exposition. All our crucial results extend under the opposite tie-breaking rule (i.e., conflict is preferred to status-quo) or no tie-breaking rule.

[20] See Lemma 1 in Akerlof and Holden (2012) for a closely related derivation, and Drugov and Ryvkin (2017) on the monotonicity of a_l in l due to the increasing failure rate of ϵ_i. An alternative approach that

the pair-swap, best-shot and worst-shot success functions[21] with a homogeneous impact function.[22] We prove this in Appendix A.2, also arguing that (6) holds for all success functions defined by weighted averages of success functions from these three families. Assuming that (6) holds, our first proposition shows that, in any subgame, equilibrium rent dissipation is a measure of inequality that belongs to the family of Generalized Gini coefficients in relative form.

Proposition 1 *Let p satisfy (6). In any subgame, equilibrium rent dissipation is a Generalized Gini coefficient in relative form, i.e., $R(v, x^*) = I(v)$ for some series $a_1, \ldots, a_n$ that satisfies the aforementioned restrictions.*

The intuition of Proposition 1 is straightforward. Risk neutrality implies the additive separability of a player's payoff by different prizes, which together with (6) guarantees that aggregate equilibrium effort can be written as a weighted average of such prizes. Then, equilibrium rent dissipation is proportional to this particular class of inequality measures because, being linear in each prize's share of the total value, we can think of these measures as weighted distances between pairs of prizes which capture the incentives to be ranked above/below others and climb the social ladder. More generally, the equivalence of equilibrium rent dissipation to this class of inequality measures implies that the former: satisfies the Pigou-Dalton transfer principle; is scale invariant; decreases with positive translations of the prize distribution. These are well-known concepts in inequality measurement. Roughly speaking, the Pigou-Dalton transfer principle requires an inequality measure to be non-increasing in transfers from a higher prize to a lower prize, scale invariance demands an inequality measure to be constant in the multiplication of all prizes by the same positive constant, and a positive translation of the prize distribution adds the same positive constant to all prizes.[23]

Next, we solve for the first stage of our game: the conflict outbreak. Our next proposition identifies a simple condition that determines whether there is peace or conflict depending on the prize distribution.

Proposition 2 *Let p satisfy (6). In equilibrium, peace is sustained if and only if $I(v) \geq D(v, k)$.*

leads to (6) is to allow for ranking-specific *iid* noise (instead of player-specific) and ranking-specific score functions that depend on efforts. See Remark 1 in Vesperoni (2016) for a derivation of the pair-swap model in this fashion.

[21] To the best of our knowledge, these are the success functions for multi-prize contests with axiomatic and stochastic foundations. For the best-shot and worst-shot models see Fu and Lu (2012), Fu et al. (2014) and Lu and Wang (2015, 2016). For the pair-swap model see Vesperoni (2016).

[22] Roughly speaking, the impact function defines the way the effort of each player enters the success function. An impact function $f : \mathbb{R}_+ \to \mathbb{R}_+$ is said to be homogeneous if $f(x_i) = x_i^\alpha$ for some $\alpha > 0$. See Skaperdas (1996) for a motivation of the impact function $f(x_i) = x_i^\alpha$ based on the homogeneity of degree zero of the success function.

[23] We wish to remark that, for a broader class of contests than the ones that satisfy (6), an analogous (but not necessarily linear) relation can be found between equilibrium efforts and the Generalized Gini coefficients in absolute form. For example, one could consider best-shot, worst-shot or pair-swap success functions with a non-homogeneous impact function. We opt for a homogeneous impact function as it simplifies exposition by delivering a closed-form solution for equilibrium rent dissipation.

Proposition 2 states that conflict initiates when inequality is lower than deprivation. This may seem counter-intuitive at first, as inequality is generally considered to be a precursor of social conflict. However, by Proposition 1, the cost of conflict is an increasing function of inequality. Therefore, high inequality can dissuade players from initiating conflict. On the other hand, if inequality is lower than deprivation, the status-quo is very unfavorable to the k^{th}-poorest player and the prospect of achieving a higher prize dominates. To see the intuition behind this result, let i be the k^{th}-poorest player and consider a Pigou-Dalton transfer that leaves i's prize unchanged. As the mean prize is unaffected by such transfer, i's deprivation is also unaffected, while as inequality decreases player i becomes unambiguously more likely to reject the status-quo. On the other hand, consider now a Pigou-Dalton transfer that increases i's prize. Here, inequality decreases but i's deprivation also decreases. So, it is not immediately clear whether player i should become more or less likely to reject the status-quo as this depends on the exact levels of inequality and deprivation.

For precision of the discussion (in particular, to clarify the issue of existence of an equilibrium) we now analyze our game using the pair-swap success function introduced in Vesperoni (2016). To our knowledge this model has not been analyzed before in terms of equilibrium behavior, while the best-shot and worst-shot models have already been analyzed in (among others) Clark and Riis (1998) and Fu et al. (2014).[24] Denoting by $A_x \subseteq N$ the set of active players ($i \in A_x$ if and only if $x_i > 0$) and by $S_x \subseteq \mathcal{R}$ the set of rankings where no active player is ranked below an inactive player ($r \in S_x$ if and only if $r(i) < r(j)$ for any $i, j \in N$ with $x_i > x_j = 0$), the pair-swap success function with homogeneous impact function is

$$\tilde{p}(r,x) := \begin{cases} \frac{\prod_{i \in A_x} (x_i)^{-\alpha r(i)}}{\sum_{r' \in S_x} \prod_{i \in A_x} (x_i)^{-\alpha r'(i)}} & \text{if } r \in S_x \text{ and } A_x \neq \emptyset, \\ 1/|\mathcal{R}| & \text{if } A_x = \emptyset, \\ 0 & \text{otherwise,} \end{cases} \tag{7}$$

for some $\alpha > 0$ (i.e., the exponent of the impact function, or the impact factor for short). Our next proposition shows that, under a restriction on the impact factor α, there exists an equilibrium where rent dissipation is a linear function of the standard Gini coefficient of the prize distribution, $G(v)$.

Proposition 3 *Let $p = \tilde{p}$. If $\alpha \in (0, 1/[2(n-1)]]$ there exists an equilibrium where, in each subgame, the equilibrium effort profile $\tilde{x}^* \in X$ is such that $R(v, \tilde{x}^*) = \alpha n G(v)/2$.*

Proposition 3 identifies a sufficient condition for the existence of an equilibrium based on a restriction on the impact factor that guarantees the global concavity of the payoff function of a player when other players exert equilibrium efforts.[25] Note that, in contrast to previous approaches in the literature, this condition is free of restrictions on the prize distribution, which is crucial to assess the effects of inequality on conflict.[26] Combining Propositions 2 and 3, we obtain the following.

[24] We provide a comparison with the best-shot and the worst-shot models in Appendix A.2.

[25] More generally, as Vesperoni (2016) argues via a three-player example, the restriction on α is stronger than necessary, and an equilibrium exists for $\alpha > 1/2(n-1)$ but not 'too large'.

[26] For example, Akerlof and Holden (2012) require consecutive top prizes to be more distant than

Corollary 1 *Let $p = \tilde{p}$ with $\alpha \in (0, 1/[2(n-1)]]$. There exists an equilibrium where peace is sustained if and only if*

$$\alpha n G(v)/2 \geq D(v,k). \tag{8}$$

Condition (8) states that peace is sustained if and only if the Gini coefficient is sufficiently larger than the deprivation coefficient, where the necessary gap decreases in n and α. Let us briefly elaborate on the role of these two parameters. Firstly, the impact factor (α) measures how discriminative the conflict technology is, in the sense that the higher α is the lower is the role played by luck in determining the outcome of the conflict. Clearly, a more discriminative conflict leads to higher effort costs and renders conflict outbreak less attractive. On the other hand, the role played by the number of players (n) is best understood by considering a population replication, i.e., the cloning of each player and each prize by a given number of times adjusting k so that k/n remains constant.[27] One can show that both $G(v)$ and $D(v,k)$ are invariant to population replication. So, the left hand-side of (8) is linear in n while the right hand-side is constant, and a sufficiently large population replication can reverse a situation of conflict into peace.[28]

Figure 1 illustrates the interaction between the Gini coefficient and the deprivation coefficient in determining conflict outbreak with a five-player example. Note that, while $T(v) = T(v') = 35$, the prize distribution v is more unequal than the prize distribution v' ($G(v) = .32 > G(v') = .30$). On the other hand, the deprivation coefficients of v and v' are identical for $k = 1$ ($D(v,1) = D(v',1) = 1$) and inversely ordered for $k = 2$ ($D(v,2) = 0 < D(v',2) = .14$). Letting $\alpha = 1/[2(n-1)] = 1/8$ (i.e., the upper bound of the impact factor according to Proposition 3), we obtain $\alpha n/2 = .31$. Then, by Corollary 1, given any $\alpha \in (0, 1/[2(n-1)]]$, one can show that for $k = 1$ we have conflict under both v and v', while for $k = 2$ we have peace under v and we have conflict under v'.

consecutive bottom prizes (see Lemma 2, p. 295). Similarly, Clark and Riis (1998) and Fu et al. (2014) require a certain number of bottom prizes to be zero (see Section 2.1 and Theorem 6, p. 132, respectively). In our setting, having prizes of zero value at the bottom of the distribution implies $D(v,k) = 1$ (unless k is very large), so that by Proposition 2 there is always conflict.

[27] To see an example, consider $n = 3$, $k = 1$ and $v_1 = 3$, $v_2 = 2$, $v_3 = 1$. A population replication by a factor of 2 leads to $n = 6$, $k = 2$ and $v_1 = v_2 = 3$, $v_3 = v_4 = 2$, $v_5 = v_6 = 1$.

[28] We argue in Appendix A.2 that, also for the best-shot and the worst-shot models, equilibrium rent dissipation always increases in population replication, although the linearity in n is lost.

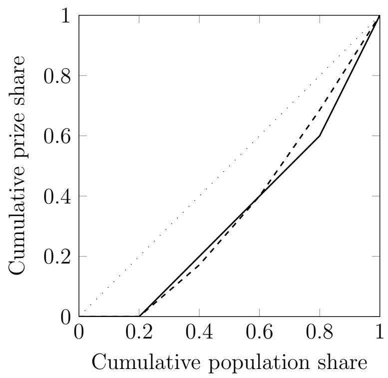

Figure 1: The solid line and the dashed line respectively represent the Lorenz curves for the two prize distributions $v = (14, 7, 7, 7, 0)$ and $v' = (11, 10, 8, 6, 0)$.

3.2 Extensions

Until now we have assumed that players' payoffs are perfectly symmetric in the occurrence of conflict, that the status-quo prizes are unaffected by conflict outbreak, and that we can think of social classes as unitary players. We now relax these assumptions to show that our core results persist under certain conditions.

First, we let a fraction of each status-quo prize to be destroyed in the occurrence of conflict. Intuitively, this should capture inefficiencies of conflict outbreak that go beyond the exertion of efforts. We assume that such fraction is a function $\gamma : \mathbb{R}_+ \to \mathbb{R}_+$ of the value of the corresponding prize, so that $\gamma(v_l)$ is the destroyed part and $v_l - \gamma(v_l)$ is the surviving part of v_l. We sometimes refer to the surviving part as the transformed prize, which we assume to be non-negative (i.e., $v_l - \gamma(v_l) \geq 0$). Second, we introduce heterogeneous head-starts that we model as non-negative constants added to players' efforts, representing pre-committed minimal effort levels not effecting the (current) effort costs.[29] As we interpret head-starts as previous investments in self-protection, it seems natural that they are proportional to the status-quo prizes according to some function $\phi : \mathbb{R}_+ \to \mathbb{R}_+$ with $v_l - \phi(v_l) \geq 0$, where $\phi(v_i)$ denotes player $i \in N$'s head-start and $y_i = \phi(v_i) + x_i$ is her effective effort. Third, we think of each player $i \in N$ as a social class constituted by a continuum of individuals of mass $m_i > 0$ taking a collective decision on the level of their collective effort x_i. In this setting, it seems reasonable that if an effort level is a Condorcet winner within a class (i.e., it is preferred by a majority of class members to any alternative effort level) it should be the chosen one by the class.[30] For

[29] We consider this particular type of asymmetry as the analysis of the ongoing conflict remains tractable while interesting dynamics are introduced in the determination of conflict outbreak. Other types of asymmetry such as heterogeneous marginal costs of effort render the analysis of equilibrium efforts under general prize structures a nearly impossible task. The analysis of equilibrium efforts under restricted prize structures suggests that these other types of asymmetry tend to reduce the aggregate effort exerted, thus lowering equilibrium rent dissipation. However, it is not immediately clear how these asymmetries should affect the likelihood of conflict outbreak.

[30] We discuss the plausibility of this and other assumptions at the end of this section.

each $i \in N$, we assume that the members of class i share their collective costs equally (so that each member carries the cost x_i/m_i) while they may share unevenly their collective benefits (i.e., the status-quo prize v_i and the transformed prize achieved through conflict). Assuming that the distribution of benefits within each class is symmetric around the mean (so that it can be interpreted as 'white noise'), the median voter is the individual with average benefits within such class, and by the median voter theorem her preferred effort level is the Condorcet winner. It follows that the expected payoff of the median voter of class $i \in N$ in the event of conflict is

$$\pi_i(v, y) = \left(\sum_{r \in \mathcal{R}} p(r, y)(v_{r(i)} - \gamma(v_{r(i)})) - y_i + \phi(v_i) \right) / m_i,$$

where $y := (y_1, \ldots, y_n)$ denotes an arbitrary vector of classes' effective efforts while her status-quo payoff is v_i/m_i. Then, class $i \in N$ chooses peace over conflict if and only if $v_i \geq \pi_i(v, y^*)$, where y^* denotes the vector of effective efforts in the symmetric interior equilibrium of the conflict subgame across social classes (where each class implements the effort level that is a Condorcet winner). On the properties of such equilibrium, the corresponding version of condition (6) is

$$\sum_{r : r(i) = l} \partial p\left(r, (y_i, y^*_{\neg i})\right) / \partial y_i \Big|_{y_i = y^*_i} = a_l / y^*_i, \tag{9}$$

where the series $a_1, \ldots, a_n$ satisfies the same restrictions as before, $y^*_{\neg i}$ is any vector of symmetric positive real numbers representing the equilibrium effective efforts of all classes other than i, and y^*_i is equal to such effective efforts so that $y^* = (y^*_i, y^*_{\neg i})$. It is straightforward that, in an interior equilibrium that is symmetric in effective efforts ($y^*_i = y^*_j$ for all $i, j \in N$), the equilibrium effort $x^*_i = y^*_i - \phi(v_i)$ is heterogeneous across classes whenever ϕ is non-constant.[31] To guarantee the existence of such equilibrium, in what follows we restrict our attention to functions ϕ such that all head-starts are lower than the equilibrium effective effort y^*_i and we assume that there is some heterogeneity across the transformed prizes, i.e., $v_l - \gamma(v_l) \neq v_{l'} - \gamma(v_{l'})$ for some $l, l' \in N$.

Generalizing the statement in Proposition 2, one can show that peace is sustained in a subgame perfect equilibrium with symmetric effective efforts if and only if the following condition holds for more than $n - k$ classes,

$$I(\tilde{v}) \geq 1 - \left(\frac{v_i - \phi(v_i)}{T(\tilde{v})/n} \right), \tag{10}$$

where $\tilde{v} := (v_1 - \gamma(v_1), \ldots, v_n - \gamma(v_n))$ denotes the vector of transformed prizes and the inequality index $I(\tilde{v})$ is computed employing the series $a_1, \ldots, a_n$ identified in (9). For simplicity, suppose that the functions γ and ϕ are linear, $\gamma(v_l) = b_1 + b_2 v_l$ and $\phi(v_l) = c_1 + c_2 v_l$, where the intercept parameters b_1, c_1 are non-negative and the slope parameters b_2, c_2 take value in $(-1, 1)$, also guaranteeing that the necessary restrictions

[31] Note that both x^*_i and y^*_i are independent of m_i for each $i \in N$ since this parameter only rescales the conflict payoff π_i without affecting the incentives to exert effort.

for the existence of the symmetric equilibrium are met and that both the values $\gamma(v_l)$ and $\phi(v_l)$ and the differences $v_l - \gamma(v_l)$ and $v_l - \phi(v_l)$ are non-negative for each $l \in N$, in line with the intuition. Note that this allows γ and ϕ to be either increasing or decreasing. Roughly speaking, the function ϕ may be decreasing (increasing) if there is a trade-off (complementarity) between income, represented by the status-quo prize, and the pre-committed investment in self-protection represented by the head-start. Similarly, the function γ may be increasing or decreasing depending on the specific features of conflict outbreak, i.e., whether high or low incomes are destroyed the most in the event of conflict.

It is straightforward that, by the linearity of ϕ, the right hand-side of (10) increases in v_i and peace is sustained if and only if the k^{th}-poorest class prefers so, i.e.,

$$I(\tilde{v}) \geq 1 - \left(\frac{v_{n+1-k} - \phi(v_{n+1-k})}{T(\tilde{v})/n} \right). \tag{11}$$

Moreover, by (1) and the linearity of γ the left hand-side can be written as

$$I(\tilde{v}) = I(v) / \left[1 - \frac{nb_1}{(1-b_2)T(v)} \right],$$

so that by our linearity assumptions peace is sustained if and only if

$$I(v) \geq \left[1 - \frac{nb_1}{(1-b_2)T(v)} \right] \left[1 - \frac{(1-c_2)v_{n+1-k} - c_1}{(1-b_2)T(v)/n - b_1} \right].$$

Note that, for any given $T(v)$, the right hand-side of this condition is proportional to the deprivation coefficient $D(v,k) = 1 - v_{n+1-k}/[T(v)/n]$.[32] Then, since the condition for peace is qualitatively the same as the one in Proposition 2, we can conclude that our previous analysis extends if γ and ϕ are linear.

While these results are far from a general analysis, they suggest that our theoretical predictions are robust to these extensions under certain conditions. Before concluding this section, we briefly discuss alternative assumptions that may or may not work against our results. Note that, by (1), the linearity of γ is essential for the proportionality between $I(\tilde{v})$ and $I(v)$ and any alternative restriction on γ would blur the results. On the other hand, we now argue that the linearity of ϕ is not so crucial. For brevity, in what follows we exclusively focus on ϕ being increasing/decreasing and convex/concave. First, if ϕ is decreasing the right hand-side of (10) increases in v_i and peace is sustained if and only if the k^{th}-poorest class prefers so, leading to (11). Second, assuming that ϕ is increasing and strictly concave (convex), it is easy to verify that the right hand-side of (10) can be non-monotonic in v_i. Roughly speaking, we should expect the right hand-side of (10) to be minimized (maximized) when v_i takes 'intermediate values' under strict concavity (convexity) of ϕ, which implies that Pigou-Dalton transfers that reduce inequality may

[32]Letting $b_1 = c_1 = 0$, this proportionality is evident as the condition reduces to $I(v) \geq 1 - \left(\frac{1-c_2}{1-b_2}\right) \frac{v_{n+1-k}}{T(v)/n}$, where the right hand-side is a linear transformation of $D(v,k)$.

also reduce (increase) the right hand-side of (10) if they concentrate the prize distribution around these intermediate values. All in all, we can conclude that the core prediction of our model (that higher inequality leads to peace) is likely to extend if ϕ is decreasing or if ϕ is increasing and strictly convex, while it may be blurred if ϕ is increasing and strictly concave.

Finally, we wish to point out that the extension to players as social classes strongly relies on ruling out collective action problems such as free-riding (see, e.g., Olson, 1965) in the determination of the collective effort of each social class. While this seems plausible for social classes of limited size (such as the ruling elite), it may be unrealistic for the working class as a whole unless strong coordination is achieved via trade unions and the like.[33] Another crucial restriction is that the distribution of benefits within each class is symmetric around the mean. Intuitively, this seems plausible if we think of social classes as groups of individuals defined by their homogeneous roles in the production process, which in turn determine their economic rent up to 'white noise'.[34]

4 Empirical evidence

In this section we present empirical evidence for our theoretical predictions concerning the relation between conflict outbreak, inequality, and deprivation. We use an unbalanced yearly panel data of 41 high and middle income countries between years 1980 and 2015, considering the income distribution and the number of labor strikes per capita in each country and year as proxies for the prize distribution and conflict outbreak, respectively. Accordingly, in this section we use the words conflict and strike, and income and prize interchangeably. In this context, Proposition 2 suggests that the Gini coefficient should be negatively correlated and the deprivation coefficient should be positively correlated with the number of labor strikes per capita in the same country and year. The empirical evaluation of these two core hypotheses is what we pursue in this section.

Our empirical strategy is based on a an ordinary fixed-effects model as a benchmark, and a set of alternative specifications to control for reverse causality based on an instrumental variable approach using the international prices of oil or coal as proxies of shocks to the income distribution that are exogenous to the occurrence of labor strikes within each country. Our selection of countries roughly coincides with the OECD members and a few Latin American and Asian countries, and it is purely led by maximizing (reliable) data availability. For each country and year, our data is directly obtained or calculated

[33] From a technical viewpoint, our restriction is functional to the neutrality of equilibrium effort in class size, which is crucial for the tractability of our model as pointed out in Footnote 29. Note that this neutrality is partially justified by the arguments in Esteban and Ray (2011), whose model is based on the assumption that classes of larger size should be better at mobilizing for conflict due to economies of scale in effort exertion. Intuitively, these scale effects may counterbalance the aforementioned free-riding problem, leaving the overall effect theoretically ambiguous.

[34] This assumption may be unrealistic for societies where certain racial/cultural traits are salient in determining the distribution of income across individuals with comparable roles in the production process.

from a combination of datasets including International Labor Organization's data for the occurrence of strikes, various sources within the World Income Inequality Database on the Gini coefficients and the deprivation coefficients, and World Bank's data for all control variables and instrumental variables. Exact data sources, definitions, notes, and summary statistics are presented in Tables 2-5 in Appendix A.3.

To motivate our analysis, we start with some stylized facts about trends in income inequality and labor strikes in the second part of the 20th century. It is well-known that income inequality in developed countries progressively decreased in the first part of the 20th century, reaching minimum levels in the 1970s. Since then, income inequality has been steadily growing and, lately, has reached levels (still lower but) comparable to the late 19th century when roughly 80% of economic resources were in the hands of 20% of the population (see, e.g., Piketty, 2015). As an interpretation of this U-shaped trend in inequality, it is generally acknowledged that from the 1970s onwards the industrial organization of developed countries has been reshaped by a complex system of economic and political forces collectively referred to as 'globalization' (e.g., independence of colonies, rise of developing economies, relocation of low-tech production overseas, specialization in high-tech production) which caused a structural increase in income inequality (see, e.g., Autor et al., 2003 on the USA; Goos and Manning, 2007 on the UK; Goos et al., 2014 on 16 Western-European countries). On the other hand, through the second half of the 20th century, the occurrence of labor strikes in developed countries roughly followed an inverse U-shaped trend with a maximum in the 1970s, and since then labor strikes have become much less frequent reaching minimum levels in the previous decade (see, e.g., Brandl and Traxler, 2010; Hamann et al., 2013). These opposite trends in income inequality and strike activity are partially visualized in Figure 2, which plots yearly averages from 1980 to 2015 across our sample of high and middle income countries excluding Latin American ones. The equivalent trends for Latin America are presented in Figure 3, as they are reversed with respect to the rest of the sample for the last two decades (see also, e.g., Lustig et al., 2016). Note that, in both subsamples, income inequality and strike activity tend to move in opposite directions, thus in line with our theoretical predictions.

Figure 2: Trends in the Gini coefficient and number of strikes per capita for the countries that are not Latin American within our sample. The observations are averaged across all relevant countries for each year.

Figure 3: Trends in the Gini coefficient and number of strikes per capita for Latin American countries within our sample. The observations are averaged across all relevant countries for each year.

4.1 Methodology

We use Latin letters for raw variables and Greek letters for the logarithmized values of these variables. Our dependent variable is the logarithm of the number of labor strikes per capita, $\Sigma := \log(S)$, and the independent variables of main interest are logarithms of the Gini coefficient, $\Gamma := \log(G)$, and the deprivation coefficient, $\Delta(v,k) := \log(D(v,k))$. We calculate $D(v,k)$ using the quintiles of the corresponding income distribution, letting $n = 5$ and for each $k \in N$ computing $D(v,k)$ as the income share attached to the k^{th}-poorest 20% of the population. We focus on the values $k \in \{1,2,3\}$, which lead to the three deprivation coefficients $D(1)$, $D(2)$, and $D(3)$.[35] As control variables, we use the logarithms of per-capita national income ($\Upsilon := \log(Y)$), population size ($\Pi := \log(P)$), the (overall) unemployment rate ($\Psi := \log(U)$), the (value-added) share of the manufacturing sector in GDP ($\mu := \log(M)$), and year dummies (or a yearly time trend depending on the estimation method, see below).[36]

As a benchmark, we estimate an ordinary fixed-effects model given in the following equation,

$$\Sigma_{it} = \alpha_i + \Gamma_{it}\alpha_\Gamma + \Delta_{it}(k)\,\alpha_\Delta + \boldsymbol{\chi}'_{it}\boldsymbol{\alpha}_\chi + \mathbf{T}'\boldsymbol{\alpha}_T + u_{it}, \tag{12}$$

denoting the country and the year of an observation by the subscripts i and t, respectively, the country-specific time-invariant effects by α_i, and the error term by u_{it}, which is allowed to be correlated with α_i. All control variables are represented in the 4×1 vector $\boldsymbol{\chi}_{it}$ and all year dummies are represented in the 36×1 vector $\mathbf{T}$. While we should expect these empirical estimations to confirm our theoretical predictions, this is clearly not enough to prove a causal effect from income inequality to strike activity. Intuitively, the causal relationship could entirely go in the opposite direction, from strikes to income inequality, as strikes are typically meant to redistribute income from the owners of the means of

[35] We suppress v in $D(v,k)$ and $\Delta(v,k)$ for brevity.

[36] For brevity we only display the significant year dummies in our estimation tables.

production to the workers, if successful. For robustness of our results, we now consider a set of alternative specifications that should be immune to this problem.

Taking (12) as a benchmark, we employ an instrumental variable (IV) approach to control for the aforementioned reverse causality (and other potential endogeneity problems) using the global prices of oil or coal as instruments for the Gini coefficient. As these commodities are crucial inputs in the production of electricity and other forms of energy, our empirical strategy relies on the role of their prices in changing the relative costs of labor and capital and therefore the relative retribution of these factors of production. Crucially, as long as strike activities are uncoordinated across countries, the prices of these internationally traded commodities should be independent of the occurrence of labor strikes within each country, thus justifying their use as theoretically plausible instruments (the validity of this argument is tested by Sargan-Hansen J statistic[37] in our empirical models).

Let us describe our IV approach in detail. As we consider coal and oil in separate specifications, in what follows we refer to either of them as 'the commodity'. In each specification we employ as instruments for Γ the logarithm of the commodity's price at year t (ν_t) and its one-year, two-year, and three-year lagged values (ν_{t-1}, ν_{t-2}, and ν_{t-3}, respectively). Representing our instrumental variables in a 4×1 vector $\boldsymbol{\nu}_t$ and denoting the error terms for the main regression and the first-stage regression as v_{it} and w_{it}, respectively, we specify the instrumental variable model via the two equations

$$\Sigma_{it} = \beta_i + \widehat{\Gamma}_{it}\beta_{\widehat{\Gamma}} + \Delta_{it}(k)\,\beta_\Delta + \boldsymbol{\chi}'_{it}\boldsymbol{\beta}_\chi + t\beta_{trend} + v_{it}, \tag{13}$$

$$\Gamma_{it} = \gamma_i + \Delta_{it}(k)\,\gamma_\Delta + \boldsymbol{\nu}'_t\boldsymbol{\gamma}_\nu + \boldsymbol{\chi}'_{it}\boldsymbol{\gamma}_\chi + t\gamma_{trend} + w_{it}, \tag{14}$$

where $\widehat{\Gamma}_{it}$ in equation (13) denotes the fitted value of the Gini coefficient from the first-stage regression (14). Note that we do not use year dummies in the instrumental variable estimations as our instruments are country-invariant variables. To compensate for this we simply include a (yearly) time trend, t. We compute alternative estimations of the parameters of interest employing the ordinary two-stage least squares method (2SLS) and the generalized method of moments (GMM).

4.2 Results

Table 1 presents our estimation results. As we consider three alternative deprivation coefficients, we run three different estimations of the ordinary fixed-effects model (12). Similarly, for three different deprivation coefficients, two different instruments, and two different estimation methods, we run twelve different estimations for the IV model (13)-(14), leading to the fifteen estimations in Table 1.

Our results show that, first, the estimated coefficient of the (logarithmized) Gini coefficient is significant and has the expected (negative) sign in all specifications, both with the ordinary fixed-effects and the IV estimators. Roughly speaking, 1% increase in the Gini

[37]For more information see Baum et al. (2007).

coefficient leads to 3.5% decrease in the number of strikes according to the ordinary fixed-effects model, and 8% − 15% decrease according to the IV models. Similarly, the estimated coefficients for the (logarithmized) deprivation coefficients all have the expected (positive) sign, except for the ordinary fixed-effects regression using $\Delta(1)$. However, the significance of the deprivation coefficient is confined to (all) IV regressions using GMM (except for the regression using $\Delta(2)$ and logarithm of oil price as an instrument for the Gini coefficient together). One possible reason for the weak significance of the deprivation coefficient is the possible reverse causality between Gini coefficient and strikes in the ordinary fixed-effects models (note that this significance turns stronger when reverse causality is controlled for in the IV models). Secondly, 2SLS is a less efficient estimator than the GMM regarding our IV models (see the differences between standard errors of the coefficients estimated by the two estimators in Table 1). All in all, these results provide empirical evidence in support of our two core hypotheses: that inequality is negatively and deprivation is positively related to conflict outbreak.

Regarding the first-stage IV regressions,[38] the estimated coefficients for our instruments (the logarithms of coal and oil prices) are statistically insignificant in their current values, but all negative and generally significant in their lagged values. More specifically, all lagged values of coal prices are significant for the regressions using $\Delta(1)$, while the two-year lagged coal price loses significance for the regressions using $\Delta(2)$ and $\Delta(3)$. Similarly, the one-year and three-year lagged oil prices are significant for the regressions using $\Delta(1)$ while the one-year lagged oil price loses significance for the regressions using $\Delta(2)$ and $\Delta(3)$. These results imply that the international prices of oil and coal have a delayed and smoothing effect on the income distribution, which is expected as the substitution between capital and labor is delayed by short-run technological constraints. Note that the Sargan-Hansen J tests for orthogonality of our instruments to the error term in equation (13) confirms that our instruments are empirically valid in all estimations.

Finally, there are two control variables that occasionally attain significant coefficients in our estimations. The first one is the logarithm of population, Π, whose estimated coefficient is negative and significant for all specifications. Recall that, by Corollary 1, a sufficiently large population replication may reverse a situation of conflict into peace. Thus, we theoretically expect highly populated countries to have less labor strikes per capita, all else equal, which is confirmed in our estimations. The second one is the logarithm of unemployment rate, Ψ, whose coefficient is negative for all empirical specifications and it is statistically significant for the ordinary fixed-effects model. This result may reflect the increase in the opportunity cost of strike activity when the unemployment rate increases within a country.

To summarize, the theoretical results we obtain from our model are generally validated in the data: income inequality reduces, and deprivation increases the number of conflict outbreaks in the form of labor strikes per capita. Moreover, the negative coefficient of population size can also be interpreted in line with our theoretical predictions.

[38] First-stage regressions with 2SLS and GMM are presented in Table 6 in Appendix A.3.

Table 1: Estimation results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ
Γ	-3.420***	-3.575***	-3.523***	-11.37**	-12.65**	-14.07**	-10.81***	-14.13***	-15.87***	-8.217**	-8.930**	-10.20**	-7.503***	-9.762***	-11.44***
	(1.147)	(1.111)	(1.075)	(4.789)	(5.470)	(6.234)	(4.129)	(4.945)	(5.514)	(3.347)	(3.803)	(4.720)	(2.358)	(3.022)	(3.672)
$\Delta(1)$	-0.0263			1.529			2.446*			1.071			1.758*		
	(0.905)			(1.465)			(1.360)			(1.148)			(1.059)		
$\Delta(2)$		0.149			1.234			2.240**			0.835			1.194	
		(0.483)			(1.074)			(0.932)			(0.804)			(0.737)	
$\Delta(3)$			0.0412			0.460			0.598**			0.290			0.356*
			(0.137)			(0.312)			(0.274)			(0.238)			(0.197)
Υ	0.0393	0.00210	0.00412	-0.203	-0.149	-0.177	-0.331	-0.224	-0.306	-0.0766	-0.0326	-0.0688	-0.0834	-0.0603	-0.158
	(0.275)	(0.287)	(0.290)	(0.278)	(0.267)	(0.295)	(0.273)	(0.255)	(0.269)	(0.238)	(0.232)	(0.256)	(0.230)	(0.228)	(0.248)
Π	-3.623*	-4.147**	-4.143**	-5.204*	-5.787*	-6.110*	-5.306*	-6.150*	-6.858*	-4.339*	-4.763*	-5.091*	-3.706	-4.566*	-5.046*
	(1.896)	(1.869)	(1.877)	(3.053)	(3.263)	(3.586)	(3.016)	(3.226)	(3.510)	(2.405)	(2.489)	(2.741)	(2.300)	(2.381)	(2.617)
Ψ	-0.433*	-0.457*	-0.456*	-0.109	-0.0773	-0.0234	-0.132	-0.0507	0.0413	-0.222	-0.210	-0.162	-0.267	-0.207	-0.110
	(0.235)	(0.231)	(0.232)	(0.240)	(0.268)	(0.299)	(0.219)	(0.258)	(0.290)	(0.197)	(0.211)	(0.239)	(0.171)	(0.197)	(0.229)
μ	-0.285	-0.346	-0.336	-0.151	-0.118	-0.0205	0.0276	0.0565	0.122	-0.194	-0.178	-0.101	-0.122	-0.0406	0.00771
	(0.741)	(0.732)	(0.716)	(0.814)	(0.805)	(0.848)	(0.711)	(0.703)	(0.737)	(0.766)	(0.747)	(0.772)	(0.683)	(0.672)	(0.690)
year=1981	0.921***	0.960***	0.969***												
	(0.229)	(0.217)	(0.217)												
trend				0.0249	0.0308	0.0362	0.0303	0.0426	0.0555	0.00407	0.00730	0.0135	-0.00664	0.00646	0.0185
				(0.0436)	(0.0458)	(0.0503)	(0.0411)	(0.0438)	(0.0464)	(0.0333)	(0.0343)	(0.0393)	(0.0295)	(0.0313)	(0.0355)
Observations	538	529	529	537	528	528	537	528	528	535	526	526	535	526	526
Within R^2	0.338	0.344	0.344	0.179	0.144	0.083	0.188	0.077	-0.001	0.255	0.247	0.214	0.259	0.225	0.177

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

(1)-(3): ordinary fixed-effects estimators.

(4)-(6) & (10)-(12): 2SLS IV estimators using coal and oil prices as instruments for the Gini coefficient, respectively.

(7)-(9) & (13)-(15): GMM IV estimators using coal and oil prices as instruments for the Gini coefficient, respectively.

Standard errors are in parentheses and are clustered by country and heteroscedasticity robust in all regressions.

5 Conclusion

In this paper we study the relation between inequality and conflict both from theoretical and empirical perspectives. From a theoretical viewpoint, we model conflict as a multi-prize contest and establish a link between equilibrium rent dissipation and the inequality of the contested resources in the form of a generalized Gini coefficient of the prize distribution. In this setting, we find that higher inequality leads to higher intensity of conflict, provided that such conflict has been initiated. Importantly, we identify a sufficient condition for the existence of an equilibrium that is valid for all prize distributions, which we feel is crucial to assess the effects of inequality on conflict in full generality.

Given this, we extend this contest model to predict conflict outbreak. We assume that there is a status-quo prize distribution, and that a conflict to reshuffle these prizes is initiated if and only if at least k players prefer so. Within this framework, we show that conflict can occur when inequality across prizes is relatively low, as players expect low intensity of conflict and therefore moderate effort costs. On the other hand, conflict can also occur when deprivation is relatively high, because the poorest players are highly dissatisfied with the status-quo. The occurrence of conflict is fully determined by the interaction of these two variables, where the former must be lower than the latter to achieve conflict outbreak.

We conclude our theoretical analysis by considering three robustness checks. First, we consider asymmetries across players in terms of heterogeneous head-starts proportional to their status-quo prizes, showing that our results directly extend if this proportionality is governed by a linear function. Second, we show that our analysis extends also if we let a fraction of each status-quo prize to be destroyed in the occurrence of conflict, as long as this fraction is a linear function of the value of each status-quo prize. Note that these linear functions can be either increasing or decreasing, thus capturing a wide range of possibilities. Third, we explicitly model each player's behavior as the collective decision of a social class whose members share the benefits heterogeneously and the costs equally, and take decisions by majority rule. In this setting, we show that our results persist if the distribution of benefits is symmetric around the mean within each class, no matter how differently sized the classes are. While these findings confirm the solidity of our theoretical predictions, we wish to remark that there are many alternative ways to model these effects and a thorough analysis is left to future research.

Our empirical analysis consists in a test of our theoretical predictions with a panel data of 41 high and middle income countries between 1980 and 2015. For each country and each year, we approximate the prize distribution by the income distribution and conflict outbreak by the number of labor strikes per capita in the same country and year. Using ordinary fixed-effects and instrumental variable estimators (taking current and lagged oil or coal prices as instruments for the Gini coefficient), we provide robust evidence that income inequality affects conflict outbreak negatively, as expected. In line with our predictions, we also find a positive effect of deprivation on labor strikes in all our estimations, although the evidence is not always statistically conclusive.

A Appendix

A.1 Proofs

Proof of Proposition 1

In any subgame (i.e., whenever conflict occurs), the equilibrium effort $x_i^* > 0$ of each player $i \in N$ is determined by the first order condition

$$\sum_{r \in \mathcal{R}} \partial p(r, (x_i, x_{\neg i}^*))/\partial x_i|_{x_i = x_i^*} v_{r(i)} = 1. \tag{15}$$

Then, assuming (6) holds, each player $i \in N$ exerts equilibrium effort $x_i^* = \sum_{l \in N} a_l v_l$, and using (3), equilibrium rent dissipation is

$$R(v, x^*) = n \sum_{l \in N} a_l v_l / T(v) = I(v). \ \square$$

Proof of Proposition 2

In each subgame, the equilibrium payoff of player $i \in N$ is

$$\pi_i(v, x^*) = T(v)/n - x_i^* = (1 - R(v, x^*))\, T(v)/n. \tag{16}$$

This follows directly from (1) and (5) given the symmetry of the equilibrium effort profile x^* and our restrictions on the the success function (i.e., the exhaustivity and anonymity axioms), which imply $p(r, x^*) = 1/n!$ for all $r \in \mathcal{R}$ and $x_i^* = R(v, x^*)T(v)/n$ for all $i \in N$. By assumption, conflict initiates if and only if at least k players prefer so. As the equilibrium payoff from conflict given in (16) is symmetric across players, a necessary and sufficient condition for peace is that the k^{th}-poorest player (i.e., player $n + 1 - k$, given that the status-quo prizes are ordered decreasingly) does not want conflict. This is the case if and only if

$$\pi_i(v, x^*) = (1 - R(v, x^*))\, T(v)/n \leq v_{n+1-k},$$

which by Proposition 1 we can rewrite as

$$I(v) = R(v, x^*) \geq 1 - \frac{v_{n+1-k}}{T(v)/n} = D(v, k). \ \square \tag{17}$$

Proof of Proposition 3

Letting $p = \tilde{p}$, we start by deriving equilibrium rent dissipation. Suppose that $\tilde{x}^* \in X$ is a symmetric interior equilibrium. Then, for each $i \in N$, it must satisfy the first-order condition (15), which by straightforward algebra can be rewritten as[39]

$$x_i = \alpha \sum_{r \in \mathcal{R}} p(r, x) \left[\rho(i, x) - r(i)\right] v_{r(i)},$$

[39] This calculation directly follows from equation (20) in Vesperoni (2016).

where $\rho(i,x) := \sum_{r\in\mathcal{R}} p(r,x)r(i)$ is the expected level of player i in the outcome.[40] Since $\tilde{x}^*$ is symmetric, we obtain $p(r,\tilde{x}^*) = 1/n!$ and $\rho(i,\tilde{x}^*) = \sum_{l\in N} l/n = (n+1)/2$, and by the first-order condition the equilibrium effort of each player $i \in N$ is

$$\tilde{x}_i^* = \frac{\alpha}{n}\sum_{l\in N}\left(\frac{n+1}{2} - l\right) v_l, \tag{18}$$

which is positive for all prize distributions. Then, by (2), equation (18) can be rewritten as $\tilde{x}_i^* = \alpha G(v)T(v)/2$ and equilibrium rent dissipation is $R(v,\tilde{x}^*) = \alpha n G(v)/2$, which is the desired result.

We now show that the restriction $\alpha \leq 1/[2(n-1)]$ guarantees the existence of the symmetric equilibrium defined by (18). First, take any player $i \in N$ and let $x_j = \tilde{x}_j^*$ for all other players $j \neq i$, where the effort level $\tilde{x}_j^*$ is defined by (18). We want to show that, given $\alpha \leq 1/[2(n-1)]$, it is optimal for player i to exert effort $x_i = \tilde{x}_i^*$ in response to these efforts of the opponents, so that $\tilde{x}^*$ is an equilibrium. Note that $x_i = 0$ is never optimal as $x_i = \tilde{x}_i^*$ leads to a higher payoff. Then, $\tilde{x}^*$ is an equilibrium if

$$\sum_{r\in\mathcal{R}} \frac{\partial^2 p(r,x)}{\partial x_i^2} v_{r(i)} < 0 \text{ for any } x_i > 0 \text{ given } x_j = \tilde{x}_j^* \text{ for all } j \neq i, \tag{19}$$

that is, if $\pi_i(v,x)$ is a strictly concave function of x_i given the efforts of the opponents take the value specified in (18). Let $r, r' \in \mathcal{R}$ be any pair of rankings with $r(i) = r'(i) = l$ for some $l \in N$. As $x_j = \tilde{x}_j^*$ for all $j \neq i$, it is easy to show that $p(r,x) = p(r',x)$ by (7).[41] Thus, $p(r,x)$ depends only on l and x. Let $Q(l,x) := \sum_{r:r(i)=l} p(r,x)$ be the total probability of player i being ranked at level l. By (7), we can rewrite (19) as[42]

$$\sum_{l\in N} Q(l,x)\phi_\alpha(l,x)v_l - \left[\sum_{l\in N} Q(l,x)\phi_\alpha(l,x)\right]\left[\sum_{l\in N} Q(l,x)v_l\right] < 0, \tag{20}$$

where $\phi_\alpha(l,x) := l + \alpha\left(l - \sum_{m\in N} Q(m,x)m\right)^2$. Note that the left hand-side of (20) is the covariance between $\phi_\alpha(l,x)$ and v_l across all levels $l \in N$. Recall that $v_l \geq v_{l+1}$ for all $l \in N\backslash\{n\}$. Then, since $v_l > v_{l+1}$ for some $l \in N\backslash\{n\}$, (20) always holds if $\phi_\alpha(l,x)$ is an increasing function of l. The first derivative of $\phi_\alpha(l,x)$ with respect to l is positive if and only if

$$2\alpha l + 1 \geq 2\alpha \sum_{m\in N} Q(m,x)m. \tag{21}$$

For any $l \in N$ and $x \in X$, the left hand-side of (21) is larger than $2\alpha + 1$ while the right hand-side is smaller than $2\alpha n$. Then, if $\alpha \leq 1/[2(n-1)]$ the first derivative of $\phi_\alpha(l,x)$ is always positive and (20) must hold. □

[40] See Proposition 4 in Vesperoni (2016) for more on the expected level $\rho(i,x)$ and the monotonicity properties of the pair-swap success function.

[41] This directly follows from the anonymity axiom which is fulfilled by the pair-swap success function.

[42] Equation (21) in Vesperoni (2016) provides an intermediate step in this calculation.

A.2 Comparison with the best-shot and worst-shot models

We now consider the best-shot and the worst-shot success functions with homogeneous impact functions, two well-known alternatives to the pair-swap model. Let $r^{-1}(l)$ denote the candidate that occupies level $l \in N$ in ranking $r \in \mathcal{R}$, and for each level $l \in N$ define the sets $\overline{M}_l := \{h \in N : h \geq l\}$ and $\underline{M}_l := \{h \in N : h \leq l\}$, which respectively denote the sets of players ranked weakly below and weakly above level l in ranking r. The best-shot success function can be written as

$$\hat{p}(r,x) := \left(\prod_{l=1}^{|A_x|} \frac{(x_{r^{-1}(l)})^\alpha}{\sum_{h \in \overline{M}_l} (x_{r^{-1}(h)})^\alpha} \right) \left(\prod_{l=|A_x|}^{n-2} \frac{1}{n-l} \right),$$

while the worst-shot success function is

$$\check{p}(r,x) := \begin{cases} \prod_{l=2}^{n} \frac{\prod_{h \in A_x \cap \underline{M}_l \setminus \{l\}} (x_{r^{-1}(h)})^\alpha}{\sum_{j \in \underline{M}_l} \prod_{h \in A_x \cap \underline{M}_l \setminus \{j\}} (x_{r^{-1}(h)})^\alpha} & \text{if } r \in S_x \text{ and } A_x \neq \emptyset, \\ 1/|\mathcal{R}| & \text{if } A_x = \emptyset, \\ 0 & \text{otherwise.} \end{cases}$$

Denote by $\hat{x} \in X$ and $\check{x} \in X$ an equilibrium effort profile with the best-shot and worst-shot success function respectively. Depending on the success function, in a symmetric equilibrium the effort of player $i \in N$ must take value

$$\hat{x}_i^* = \frac{\alpha}{n} \sum_{l \in N} \left(1 - \sum_{h=0}^{l-1} \frac{1}{n-h} \right) v_l,$$
$$\check{x}_i^* = \frac{\alpha}{n} \sum_{l \in N} \left(\sum_{h=0}^{n-l} \frac{1}{n-h} - 1 \right) v_l,$$

which can be compared to the expression of the equilibrium effort $\tilde{x}_i^*$ induced by the pair-swap model defined in (18). Sufficient conditions for the existence of a symmetric equilibrium are discussed in Clark and Riis (1998) for the best-shot model and in Fu et al. (2014) for the worst-shot model.[43] For each of the three models (i.e., best-shot, worst-shot, pair-swap models), equilibrium rent dissipation takes the form (1), where depending on the model the coefficients are respectively, for each $l \in N$,

$$\hat{a}_l := \frac{\alpha}{n} \left(1 - \sum_{h=0}^{l-1} \frac{1}{n-h} \right),$$
$$\check{a}_l := \frac{\alpha}{n} \left(\sum_{h=0}^{n-l} \frac{1}{n-h} - 1 \right),$$
$$\tilde{a}_l := \frac{\alpha}{n} \left(\frac{n+1}{2} - l \right).$$

[43] For the best-shot model, see also Clark and Riis (1996), Fu and Lu (2009) and Schweinzer and Segev (2012).

Note that $\sum_{l=1}^{n} \hat{a}_l = \sum_{l=1}^{n} \check{a}_l = \sum_{l=1}^{n} \tilde{a}_l = 0$ and $\hat{a}_l \geq \hat{a}_{l+1}$, $\check{a}_l \geq \check{a}_{l+1}$, $\tilde{a}_l \geq \tilde{a}_{l+1}$. See Figure (4) for a graphical representation.

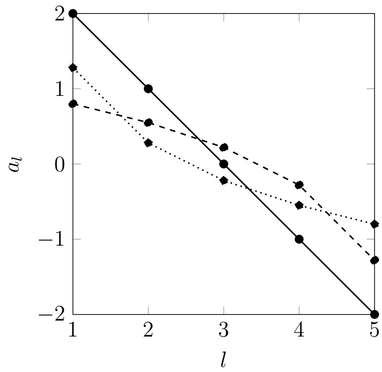

Figure 4: The solid, dashed and dotted lines respectively connect the values of the coefficients of the pair-swap model ($\tilde{a}_l$), best-shot model ($\hat{a}_l$) and worst-shot model ($\check{a}_l$) given $n = \alpha = 5$. Different values of α simply rescale all coefficients homogeneously.

It is straightforward that condition (6) holds for any success function defined via a weighted average of any number of success functions from these three families. To see this, take any $\omega_1, \omega_2, \omega_3 \in [0, 1]$ such that $\omega_1 + \omega_2 + \omega_3 = 1$ and consider the success function $p(r, x) = \omega_1 \tilde{p}(r, x) + \omega_2 \hat{p}(r, x) + \omega_3 \check{p}(r, x)$. It is straightforward that, since (6) is linear in a_l, the coefficients must take value $a_l = \omega_1 \tilde{a}_l + \omega_2 \hat{a}_l + \omega_3 \check{a}_l$ and satisfy $\sum_{l=1}^{n} a_l = 0$ and $a_l \geq a_{l+1}$. The argument directly extends to weighted averages of more than three success functions. Given this, for all these success functions equilibrium rent dissipation can be interpreted as an inequality measure of the family of Generalized Gini coefficients in relative form. So, for each of them, equilibrium rent dissipation satisfies the Pigou-Dalton transfer principle, it is scale invariant and it decreases with positive translations of the prize distribution.

We end this section by discussing the population replication principle, a well-known property in the inequality literature. We say that equilibrium rent dissipation satisfies the population replication principle if it is invariant to replicating the population, in the sense of cloning each individual and each prize a given number of times.[44] Firstly, consider the equilibrium rent dissipation of the pair-swap model, $R(v, \tilde{x}^*) = (n\alpha/2)G(v)$. It is well-known that the Gini coefficient $G(v)$ satisfies the population replication principle (see, e.g., Donaldson and Weymark, 1980). Then, equilibrium rent dissipation of the pair-swap model $R(v, \tilde{x}^*) = \alpha n G(v)/2$ increases linearly with population replication and proportionally to the degree of inequality of the prize distribution. On the other hand, equilibrium rent dissipation of the best-shot and worst-shot models can be respectively

[44]Given any population size n and parameter α, for each model we exclusively consider population replications for which the previously defined symmetric equilibrium exists.

written as

$$R(v,\hat{x}^*) = \alpha \sum_{l\in N} \left(1 - \sum_{h=0}^{l-1} \frac{1}{n-h}\right) v_l/T(v) = -\alpha(H_n - 1) + \alpha \sum_{l\in N} H_{n-l} v_l/T(v),$$

$$R(v,\check{x}^*) = \alpha \sum_{l\in N} \left(\sum_{h=0}^{n-l} \frac{1}{n-h} - 1\right) v_l/T(v) = \alpha(H_n - 1) - \alpha \sum_{l\in N} H_{l-1} v_l/T(v),$$

where H_z denotes the harmonic number

$$H_z := \begin{cases} \sum_{k=1}^{z} 1/k & \text{if } z \geq 1, \\ 0 & \text{otherwise.} \end{cases}$$

Theorem 1 in Fu and Lu (2009) and Proposition 1 in Lu et al. (2016) respectively imply that $R(v,\hat{x}^*)$ and $R(v,\check{x}^*)$ increase with population replication. Our expressions above show that in these models the effect of population replication is non-linear and, generally speaking, not straightforward to analyze as it depends on a weighted average of harmonic numbers.

A.3 Supplementary material to the empirical analysis

This section is supplementary to the empirical models presented in Section 4. The data sources and definitions are in Table 2, the summary statistics are in Tables 3-5, and the first-stage regressions for the IV model are in Table 6.

Table 2: Data sources and definitions

Variable	Source	Definition
S	International Labor Organization, ILO (2017)	Number of strikes and lockouts across all economic activities.
G	Standardized World Income Inequality Database (SWIID)	The standardized Gini coefficient as developed by Solt (2016).
$D(k)$	World Income Inequality Database 3.4, UNU-WIDER (2017)	Deprivation coefficient. Calculated as in (4) using the quintiles of the income distribution.
Y	The World Bank national accounts data, The World Bank (2017)	Gross national product per-capita (in current US$).
P	The World Bank national accounts data, The World Bank (2017)	Population level of countries.
U	The World Bank national accounts data, The World Bank (2017)	Overall unemployment rate of countries (% of total labor force).
M	The World Bank national accounts data, The World Bank (2017)	Manufacturing, value added (% of GDP). Industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs.
Crude oil and coal prices	The World Bank Data Catalog, The World Bank (2018)	Nominal prices of crude oil ($/bbl) and Australian coal ($/mt).

Table 3: Panel summary statistics of variables by country

Country	Statistic	S ($\times 10^6$)	G (%)	$D\,(1)$ (%)	$D\,(2)$ (%)	$D\,(3)$ (%)	Y (level)	P ($\div 10^3$)	U (%)	M (%)
Argentina	Mean	22.37	42.31	77.82	55.81	31.03	6,191	35,900	8.81	21.14
	St. Dev.	6.75	2.44	4.34	4.62	4.64	3,109	4,575	2.20	5.80
	Observations	13	36	34	33	33	36	36	10	36
Australia	Mean	64.01	31.2	61.13	34.93	11.14	25,843	18,700	7.02	10.62
	St. Dev.	49.87	1.52	1.51	2.44	2.23	15,781	2,531	1.82	2.28
	Observations	29	35	18	18	18	35	35	35	25
Austria	Mean	0.48	26.46	54.05	27.93	8.35	31,105	8,043	4.54	17.97
	St. Dev.	0.44	1.71	3.52	2.26	2.65	13,704	341	0.85	1.19
	Observations	27	34	23	23	23	34	34	34	34
Belgium	Mean	8.62	24.97	54.34	30.21	9.49	28,266	10,300	8.54	15.29
	St. Dev.	11.12	1.38	2.88	2.73	2.89	13,171	473	1.55	2.25
	Observations	15	37	23	23	23	37	37	34	22
Brazil	Mean	5.13	50.36	85.44	68.04	46.25	5,112	167,000	8.36	18.82
	St. Dev.	5.71	2.82	1.94	3.66	4.54	3,388	2,590	1.30	7.66
	Observations	33	36	31	31	31	32	36	19	36
Canada	Mean	13.57	29.88	64.28	34.83	10.78	27,453	30,200	8.38	10.54
	St. Dev.	10.04	1.36	3.00	3.49	3.00	13,234	3,458	1.66	0.77
	Observations	36	37	17	17	17	37	37	37	8
Chile	Mean	9.13	47.26	80.22	63.27	44.44	5,823	14,700	8.15	15.70
	St. Dev.	4.02	1.36	2.49	3.26	3.07	4,260	2,006	2.61	3.15
	Observations	30	36	18	18	18	36	36	31	36
Colombia	Mean	4.49	50.91	84.41	65.21	43.43	3,081	39,100	11.05	16.20
	St. Dev.	4.32	1.60	2.17	2.82	3.11	2,170	6,512	2.18	3.92
	Observations	22	38	27	27	27	38	38	22	38
Cyprus	Mean	29.59	30.09	57.22	34.93	15.22	18,255	939	7.28	9.11
	St. Dev.	16.94	0.31	1.51	2.80	2.93	8,616	150	4.63	4.01
	Observations	31	31	12	12	12	31	31	16	31
Czech R.	Mean	0.20	24.27	46.99	26.65	10.33	11,546	10,350	6.23	22.66
	St. Dev.	0.11	1.86	3.42	2.10	1.92	6,256	114	1.61	1.07
	Observations	12	29	27	27	27	25	29	24	24
Denmark	Mean	87.57	23.65	54.35	25.53	6.64	36,347	5,326	6.52	13.77
	St. Dev.	69.38	1.21	3.67	1.74	2.11	17,793	192	1.83	1.57
	Observations	36	37	16	16	16	37	37	34	37
Estonia	Mean	1.03	32.68	64.23	38.06	17.53	12,422	1,401	8.69	14.76
	St. Dev.	0.53	2.13	3.98	3.31	4.17	5,372	85.6	3.75	1.24
	Observations	19	29	22	22	22	17	29	27	22
Finland	Mean	96.56	23.26	47.90	25.88	8.47	29,497	5,140	8.85	20.26
	St. Dev.	126.2	2.20	3.58	3.26	2.33	13,693	206	3.84	2.99
	Observations	36	37	33	33	33	37	37	36	37
France	Mean	28.48	29.53	56.62	32.62	13.56	26,884	60,700	9.84	14.17
	St. Dev.	11.59	1.61	2.80	1.94	1.92	11,487	3,433	1.47	2.61
	Observations	25	36	25	25	25	36	36	33	36
Germany	Mean	8.38	26.88	58.15	32.91	12.78	28,187	80,600	7.49	20.68
	St. Dev.	7.27	1.36	2.89	2.80	1.44	12,439	1,754	1.81	1.26
	Observations	7	36	37	34	34	36	36	33	25
Greece	Mean	39.04	33.98	67.44	37.65	14.68	14,811	10,600	11.34	8.83
	St. Dev.	26.63	1.12	2.22	1.66	1.83	7,629	469	6.15	0.88
	Observations	19	37	22	22	22	37	37	36	22
Hungary	Mean	0.75	26.89	51.17	27.42	9.80	8,818	10,300	8.41	18.94
	St. Dev.	0.46	2.01	4.44	3.20	2.37	4,058	278	2.12	0.78
	Observations	24	37	33	32	32	24	37	25	22
Iceland	Mean	25.32	23.41	50.13	26.54	10.71	41,500	295	4.18	11.19
	St. Dev.	24.62	2.32	1.82	2.81	2.78	9,624	23.3	1.67	1.57
	Observations	13	24	12	12	12	24	24	24	19

Notes: Summary statistics from the unbalanced panel of 41 countries over 1980-2015.

Table 4: Panel summary statistics of variables by country (continued)

Country	Statistic	S ($\times 10^6$)	G (%)	$D\,(1)$ (%)	$D\,(2)$ (%)	$D\,(3)$ (%)	Y (level)	P ($\div 10^3$)	U (%)	M (%)
Ireland	Mean	13.75	31.56	59.44	36.38	14.02	25,716	3,925	11.32	22.30
	St. Dev.	13.84	1.27	2.00	2.57	2.82	16,848	457	4.98	4.22
	Observations	36	37	21	21	21	37	37	34	22
Israel	Mean	14.83	33.88	67.75	42.99	16.30	18,629	5,995	9.89	14.13
	St. Dev.	11.20	2.30	4.43	3.36	1.16	9,387	1,467	2.69	1.28
	Observations	36	37	12	12	12	37	37	27	22
Italy	Mean	19.19	32.36	63.37	36.28	12.68	22,870	57,600	9.80	16.53
	St. Dev.	8.53	1.15	2.59	1.95	2.75	10,148	1,300	1.76	1.95
	Observations	30	36	29	29	29	36	36	35	26
Japan	Mean	2.50	28.91	63.84	36.6	14.1	31,329	125,000	3.53	21.60
	St. Dev.	2.61	2.01	4.51	2.90	1.65	12,251	3,400	1.10	1.39
	Observations	34	34	6	6	6	34	34	34	20
R. of Korea	Mean	8.37	28.90	67.04	38.45	14.70	12,741	45,600	3.55	25.18
	St. Dev.	16.63	1.52	5.07	5.46	5.65	8,458	3,876	1.03	1.80
	Observations	36	37	12	12	12	37	37	37	37
Mexico	Mean	2.65	46.41	80.15	59.41	37.67	5,653	98,200	4.04	18.44
	St. Dev.	5.70	0.98	2.69	3.40	3.69	2,916	17,300	1.13	2.27
	Observations	36	37	15	15	15	37	37	27	37
Netherlands	Mean	1.45	25.91	52.30	27.21	10.68	30,884	15,700	5.88	13.96
	St. Dev.	0.57	0.71	1.58	1.58	2.06	15,084	899	2.47	2.47
	Observations	34	37	28	28	28	37	37	32	37
New Zealand	Mean	30.75	31.34	69.71	41.4	16.38	19,848	3,845	6.19	16.31
	St. Dev.	35.58	2.38	4.54	3.60	3.57	10,729	465.2	1.87	4.41
	Observations	31	35	13	13	13	35	35	32	34
Norway	Mean	3.34	24.03	57.56	29.21	8.29	47,786	4,508	3.90	9.53
	St. Dev.	1.98	1.26	6.78	5.71	2.19	29,975	341	1.13	1.93
	Observations	31	37	33	33	33	37	37	35	37
Peru	Mean	13.54	51.74	80.59	59.13	34.51	2,522	24,900	7.59	15.40
	St. Dev.	15.60	3.38	4.35	5.32	5.55	1,754	4,270	1.19	0.85
	Observations	36	37	22	22	22	37	37	15	26
Poland	Mean	40.98	29.86	59.20	34.08	13.57	7,824	38,074	12.5	16.59
	St. Dev.	87.91	2.13	6.07	4.09	2.57	4,311	468.9	4.09	1.18
	Observations	20	34	33	33	33	25	34	25	22
Portugal	Mean	28.73	34.07	65.74	41.26	18.14	12,474	10,200	7.72	13.33
	St. Dev.	13.61	0.18	2.89	3.06	3.69	7,043	252	3.48	1.88
	Observations	28	37	22	22	22	37	37	31	22
Romania	Mean	0.96	29.59	60.88	34.34	12.35	4,791	21,571	6.80	22.69
	St. Dev.	0.93	3.60	7.63	5.05	2.41	3,516	1,198	0.70	3.34
	Observations	17	28	27	27	27	25	28	22	26
Singapore	Mean	0.31	38.46	79.49	47.22	21.68	25,682	3,920	3.92	22.63
	St. Dev.	0.10	0.87	4.81	1.77	5.52	16,564	1,020	1.13	2.90
	Observations	29	38	18	7	7	38	38	33	38
Slovakia	Mean	0.62	24.09	49.27	26.29	9.51	11,326	5,653	14.29	20.20
	St. Dev.	0.86	3.17	4.78	2.39	2.34	5,653	43.4	2.86	1.56
	Observations	22	28	26	23	23	21	28	22	21
S. Africa	Mean	10.27	57.31	86.55	73.88	56.43	4,003	43,100	24.52	17.72
	St. Dev.	9.97	1.18	2.29	3.00	3.98	1,615	7,669	1.46	3.44
	Observations	36	36	10	10	10	36	36	15	36
Spain	Mean	25.72	32.59	63.2	34.88	12.62	17,757	41,600	17.49	14.23
	St. Dev.	11.31	0.98	5.03	3.22	3.18	9,439	3,320	5.05	1.70
	Observations	36	37	29	29	29	37	37	37	22
Sweden	Mean	5.79	23.28	54.99	28.97	9.64	36,274	8,864	6.19	18.39
	St. Dev.	7.29	1.95	6.00	5.89	3.98	15,273	427	2.62	2.14
	Observations	34	36	30	30	30	36	36	33	36

Notes: Summary statistics from the unbalanced panel of 41 countries over 1980-2015.

Table 5: Panel summary statistics of variables by country (continued)

Country	Statistic	S ($\times 10^6$)	G (%)	$D\,(1)$ (%)	$D\,(2)$ (%)	$D\,(3)$ (%)	Y (level)	P ($\div 10^3$)	U (%)	M (%)
Switzerland	Mean	0.76	29.98	57.60	32.42	12.88	48,891	7,140	3.78	19.09
	St. Dev.	0.43	1.31	2.17	1.67	1.89	21,217	568.0	0.80	0.65
	Observations	36	36	13	13	13	34	36	25	26
Turkey	Mean	1.75	42.69	71.53	47.88	24.18	6,013	64,713	8.97	18.92
	St. Dev.	2.37	1.45	1.09	2.02	2.63	3,875	8,389	1.46	2.74
	Observations	23	30	14	14	14	30	30	29	30
UK	Mean	7.88	32.74	59.79	36.58	15.26	27,811	59,600	7.40	11.84
	St. Dev.	8.12	2.05	4.19	3.23	2.44	13,260	3,000	2.27	3.06
	Observations	36	38	36	36	36	38	38	35	28
USA	Mean	0.17	35.70	81.41	53.63	22.48	34,387	275,000	6.41	13.09
	St. Dev.	0.17	1.73	1.52	2.84	3.99	13,939	30,400	1.59	1.38
	Observations	36	37	27	27	27	37	37	37	20
Uruguay	Mean	3.37	38.92	74.62	52.43	27.84	6,716	4,420	9.62	18.22
	St. Dev.	0.67	1.81	2.48	3.40	3.31	4,516	779	2.88	6.45
	Observations	3	37	30	30	30	37	37	25	35

Notes: Summary statistics from the unbalanced panel of 41 countries over 1980-2015.

Table 6: IV estimation results: first-stage

Γ	(1)	(2)	(3)	(4)	(5)	(6)
$\log(Oil)$	0.011	0.007	0.007			
	(0.009)	(0.008)	(0.008)			
$\log(Oil)_{-1}$	-0.052**	-0.041	-0.038			
	(0.025)	(0.027)	(0.027)			
$\log(Oil)_{-2}$	-0.023	-0.011	-0.001			
	(0.025)	(0.028)	(0.028)			
$\log(Oil)_{-3}$	-0.089***	-0.083***	-0.079***			
	(0.017)	(0.018)	(0.018)			
$\log(Coal)$				0.006	0.005	0.007
				(0.007)	(0.007)	(0.007)
$\log(Coal)_{-1}$				-0.016***	-0.012**	-0.010*
				(0.005)	(0.005)	(0.005)
$\log(Coal)_{-2}$				-0.009*	-0.008	-0.007
				(0.005)	(0.005)	(0.005)
$\log(Coal)_{-3}$				-0.020***	-0.020***	-0.020***
				(0.006)	(0.006)	(0.006)
Sargan-Hansen J	3.40	3.02	2.32	6.90*	5.96	4.32
F-test	8.08***	6.45***	5.21***	7.29***	5.90***	5.21***
(of excluded instruments)						

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

(1)-(3): IV estimators (first-stage) using $D(1)$-$D(3)$, respectively, and oil prices as an instrument.

(4)-(6): IV estimators (first-stage) using $D(1)$-$D(3)$, respectively, and coal prices as an instrument.

Standard errors are in parenthesis, clustered by country, and heteroscedasticity robust in all regressions. The estimated coefficients of the exogenous variables are excluded but available on demand.

Note that first-stage regressions of 2SLS and GMM estimators are identical by construction.

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