INTERFACE

royalsocietypublishing.org/journal/rsif

Research

Cite this article: Houle C, Ruck DJ, Bentley RA, Gavrilets S. 2022 Inequality between identity groups and social unrest. *J. R. Soc. Interface* **19**: 20210725.
https://doi.org/10.1098/rsif.2021.0725

Received: 13 September 2021
Accepted: 23 February 2022

Subject Category:
Life Sciences–Mathematics interface

Subject Areas:
evolution

Keywords:
horizontal inequality, cooperation, unrest, social norms, modelling

Author for correspondence:
Christian Houle
e-mail: houlech1@msu.edu

Electronic supplementary material is available online at https://doi.org/10.6084/m9.figshare.c.5903118.

THE ROYAL SOCIETY PUBLISHING

Inequality between identity groups and social unrest

Christian Houle[1], Damian J. Ruck[2,3], R. Alexander Bentley[2,3] and Sergey Gavrilets[2,4,5,6]

[1]Department of Political Science, Michigan State University, East Lansing, MI 48824, USA
[2]Center for the Dynamics of Social Complexity, [3]Department of Anthropology, [4]Department of Ecology and Evolutionary Biology, [5]Department of Mathematics, and [6]National Institute for Mathematical and Biological Synthesis, University of Tennessee, Knoxville, TN 37996, USA

CH, 0000-0001-7231-2992; DJR, 0000-0001-8678-8852; SG, 0000-0003-1581-4018

Economic, social and political inequality between different identity groups is an important contributor to violent conflicts within societies. To deepen our understanding of the underlying social dynamics, we develop a mathematical model describing cooperation and conflict in a society composed of multiple factions engaged in economic and political interactions. Our model predicts that growing economic and political inequality tends to lead to the collapse of cooperation between factions that were initially seeking to cooperate. Certain mechanisms can delay this process, including the decoupling of political and economic power through rule of law and allegiance to the state or dominant faction. Counterintuitively, anti-conformity (a social norm for independent action) can also stabilize society, by preventing initial defections from cooperation from cascading through society. However, the availability of certain material resources that can be acquired by the state without cooperation with other factions has the opposite effect. We test several of these predictions using a multivariate statistical analysis of data covering 75 countries worldwide. Using social unrest as a proxy for the breakdown of cooperation in society, we find support for many of the predictions from our theory.

1. Introduction

Economic, social and political inequality is an inherent feature of social complexity and has profound effects on human societies [1–5]. Despite declines in the first part of the twentieth century, economic inequality has increased among Western countries since the 1970s [6], which may be responsible for economic inefficiencies [7–9], bad governance [10,11] and crime where inequality is conspicuous [12–15]. Recent quantitative studies also link economic inequality with political instability and conflict [5,16–22] for which the underlying mechanisms are poorly understood [23].

Earlier work focused on inequality between individuals and/or between households, which is sometimes referred to as vertical inequality. More recently, studies, especially those concerned with civil conflicts, have focused on horizontal inequality, i.e. economic, social and political inequality between different identity groups (e.g. ethnic, regional, religious, cultural) [24–28]. Current efforts to measure horizontal inequality [9,29–33] have not yet led to a consensus measure like those established for vertical inequality, such as income Gini coefficient [4] and income share held by the top 1% [34].

Both forms of inequality have been shown to have harmful social effects. Vertical inequality has a negative effect on economic efficiency [9], the production of public goods [10] and government quality [11]. Horizontal inequality promotes civil conflict between identity groups [24,26,35–39], increases ethnic voting [27,40], reduces public good provision [10] and destabilizes democracy [19]. Though economic grievance is often believed to be a prime motivator [41], political exclusion provides leaders with the incentive to change the status quo, e.g. by exploiting the group's beliefs concerning its religion, history, sacred values, etc. [42]. At the same time, there may be cultural and institutional mechanisms which stabilize unequal societies. A cultural norm such as 'high confidence in the state' may increase tolerance of economic inequality [43,44]. Moreover, inclusive social institutions—such as checks and balances and rule of law—decouple economic and political power, meaning elites cannot convert political power into economic gain so easily [45–47].

Social and cultural processes underling the dynamics of cooperation and conflict in heterogeneous societies are complex. Given this complexity, mathematical modelling may provide some additional insights on these dynamics. While cooperation and conflict in heterogeneous societies are richly researched, horizontal inequality is not yet well modelled mathematically, so we do not understand the logic of crucial parameters and patterns across time and heterogeneous interactions. Our goals here are, first, to develop a mathematical framework for modelling the joint dynamics of cooperation, power and inequality in heterogeneous societies, and, second, to test our model's key predictions empirically.

We build on earlier mathematical models of conflicts between different parts of the society. In particular, a number of studies [48–56] modelled contests for power between two or three factions in the society (e.g. the elite, middle class and commoners or the authoritarian government and the military or two political groups) the winner of which sets a preferred type of the economy and political arrangements (e.g. democratic or despotic). Esteban & Ray [57] studied a conflict between a number of different factions over the control of the distribution of goods produced by the society; the conflict was modelled as a Tullock contest [58,59]. Esteban & Ray [57] showed how the equilibrium contributions to conflict depend on the indices of inequality, fractionalization and polarization [60] in the society. Some models from cooperative game theory studied coalition formation [61]. In these models, the power of individual factions was constant and determined endogenously, while economic factors were disregarded. Lawson & Oak [62] introduced a novel approach focusing on the non-equilibrium dynamics of resources and power in a society with an arbitrary number of factions engaged in the redistribution of a fixed amount of resource. Previous work has not considered, however, the possibility of cooperation between factions in the production of collective goods and the associated collective action problem [63]. By contrast, our models will focus on the non-equilibrium dynamics of interactions between cooperation in the production of collective goods and conflict over their division. We will show that these processes exhibit an inherent tendency for cycling in power, inequality and economic production.

Moreover, our models will explicitly consider mechanisms for state stability, largely ignored in previous work, including the effects of social norms (conformity and allegiance to the state), decoupling between economic and political power (rule of law), heterogeneity in resources between factions and the availability of certain material resources that can be acquired by the state without cooperation with other factions. We note that some of these factors, e.g. normative commitments and conformity, are not frequently emphasized in the literature on conflicts and horizontal inequality. Nevertheless, they are firmly established in economics, psychology, sociology and cultural evolution research as important factors of human decision-making [55,64–69]. Therefore, we include them in our model.

Our models describe the processes of societal evolution at the meso-scale [70], which is intermediate between the macro-scale processes shaping the structure and demography of the society [71–74] and micro-scale processes governing the behaviour of individuals [75–80]. Our starting point is the assumption that a successful functioning of the society (both economic and political) requires mutually beneficial cooperation between its different factions. Cooperation is sustainable only if it is beneficial to all parties. Subsequently, as factions seeking to cooperate are jockeying for power, inequality among them grows and cooperation becomes no longer beneficial. Our focus is on the breakup of cooperation between factions which is a necessary condition for internal conflict and instability. Following previous work, we postulate that the horizontal inequality may enhance group grievances breaking cooperation between factions which in turn may facilitate mobilization for conflict. Rather than model conflict explicitly, we focus instead on some of its necessary conditions. Our models reveal some unexpected combined effects of interacting factors that had previously been studied separately. After formulating our model, we analyse its dynamics, describe the effects of different parameters and make several testable predictions. Finally, using a multivariate statistical analysis covering 76 countries worldwide, we find evidence consistent with some of the model's key predictions.

The paper makes both theoretical and empirical contributions. Theoretically, we develop a novel mathematical model describing the dynamics of economic cooperation and political competition in heterogeneous societies in the presence of evolving horizontal inequality. We also propose novel causal mechanisms for why horizontal inequality can lead to the breakdown of cooperation. Our work goes beyond the study of political instability. Quantitative analyses find that horizontal inequality has many effects beyond its effect on civil wars. For example, Baldwin & Huber [10] find that horizontal inequality reduces the provision of public goods. We provide causal mechanisms for why horizontal inequality leads to the breakdown of cooperation, which, in turn, reduces public good provision.

We contribute to the empirical literature on horizontal inequality and political inequality in at least two ways. First, while previous work has shown that horizontal inequality is associated with civil wars [24,26,35–39,81], coups d'etat [82] and democratic breakdowns [83], there is little work on its effect on other forms of violence. Since the model describes the mechanisms through which horizontal inequality leads to the breakdown of cooperation, the empirical analysis focuses on small-scale forms of unrest, such as riots and anti-government demonstrations, rather than civil wars or coups. The latter require more organization and do not necessarily follow directly from the breakdown of cooperation. Small-scale conflicts, on the other hand, are more spontaneous. We thus contribute to the limited quantitative literature on the effect of horizontal inequality on small-scale violence. Crucially, different forms of violence follow different processes and can have different determinants. In fact, while the previous literature has shown that vertical inequality fosters small-scale violence, most authors find that it does not encourage civil wars [20,84,85]. Second, we provide empirical evidence that certain shared cultural values can reduce the chances of instability. For example, we find that values of conformity are associated with a higher likelihood of violence. To our knowledge, we are the first to report this finding.

2. Model

We consider a society composed of n factions (i.e. political, ethnic, religious or regional groups) in discrete time. Each faction is characterized by its relative *political power* f_i ($0 \le f_i \le 1$ for all i; $\sum_{i=1}^{n} f_i = 1$). Following the general approach of Hurwic [86] to the evolution of social institutions, we assume that factions are engaged in an *economic game* about material resources and a separate *political game* about power. Specifically, at each time step the factions first cooperate or not ($x_i = 1$ or 0) in an economic nonlinear collective goods game played according to the current state of a dynamic set of rules. Then they participate in a contest for the power to change the rules of the economic game to be played at the next time step, in terms of how the collective goods are divided among the factions.

In interpreting our model, we will use the terminology of the structural-demographic theory of revolutions [71,72,87]. Accordingly, cooperating factions will be viewed as a coalition of the 'elites' led by the 'dominant faction', i.e. the faction with the largest power. Defecting factions are viewed as 'counter-elites'. In contrast to the structural-demographic theory, which focuses on the demographic sizes of different factions in the society, our emphasis will be on their political power, economic resources and cooperation among them in the production of collective goods.

2.1. Economic game

Let R_i^0 be the resource owned by faction i (endowment), E the resource owned by the society (e.g. some natural resources or some other wealth) and available for distribution among the elites, and $P(X)$ the additional resource produced by $X = \sum x_i$ cooperating factions. We will use an S-shaped production function which captures the law of diminishing return in a simple form:

$$P(X) = b\frac{X^{\kappa}}{X^{\kappa} + X_0^{\kappa}}, \qquad (2.1)$$

where b is the maximum possible benefit of the collective action, X_0 is a half-effort parameter, and κ is a steepness parameter (X_0, $\kappa > 0$) [88]. The larger X_0, the more cooperating factions X are needed to produce the goods; at $X = X_0$, the cooperating factions secure half of the maximum possible amount. As $\kappa \to \infty$, function $P(X)$ approaches a step function. It is convenient to use a scaled half-effort parameter $x_0 = X_0/n$, whose value is always between 0 and 1.

The material payoff of faction i is defined as

$$R_i(x_i) = R_i^0 + [v_i(E + P(X)) - c]x_i, \qquad (2.2a)$$

where c is the cost of a faction's effort in the collective action and v_i is the share of the collective goods $E + P(X)$ going to faction i which depends on its power:

$$v_i = \frac{f_i}{\sum_C f_j}, \qquad (2.2b)$$

where the sum is over the set C of cooperating factions. That is, the factions face a conflict over the division of jointly owned (E) and produced (P) resources. In this model of 'club goods' [89], only the coalition of elites (i.e. cooperating factions with $x_i = 1$) share the goods dividing them according to their power, whereas the counter-elites (defecting factions with $x_i = 0$) just keep their endowment R_i^0. Factions should cooperate only if their power and corresponding share of collective goods are sufficiently large [63,88,90]. Note that each time a faction moves from the elite to the counter-elite, production P is reduced which punishes the remaining cooperating elites more than the counter-elites (who have little left to lose when they defect). Also note that in models of collective action, the most important factor for agents' decision-making is the relationship between benefit and cost. In our model, the faction's benefit and cost depend on its power and effort in the collective action, respectively.

2.2. Political game

All factions in the society are engaged in a political contest the outcome of which modifies political power f_i to

$$f_i' = \frac{y_i}{\sum_j y_j}, \qquad (2.3a)$$

where y_i is the *effective effort* of faction i in the political game (the prime means the value at the next iteration). Recurrence equation (2.3*a*) is a form of the Tullock contest [59]. In general, the effectiveness of a faction in the political contest should increase with its economic resources R_i and political power f_i, with more politically powerful factions being able to use the available resource more efficiently than less politically powerful factions in shaping the rules of the economic game to their own advantage [91]. We capture these intuitions by defining y_i as

$$y_i = R_i(1 - \varepsilon + \varepsilon f_i), \qquad (2.3b)$$

where the incumbency effect parameter ε controls the strength of dependence of y_i on power f_i ($0 \le \varepsilon \le 1$). If $\varepsilon = 0$, then $y_i = R_i$ and only the amount of the faction's material resource R_i matters; if $\varepsilon = 1$, then $y_i = R_i f_i$, so that the material resource and power combine multiplicatively in defining y_i. Parameter ε captures the efficiency of 'rule of law' mechanisms in the society acting towards maintaining a level playing field and preventing politically powerful factions from bending the rules of competition in their favour. High values of ε are indicative of low degree of 'rule of law'. We note that equations (2.3*a*,*b*) defining the dynamics of power are related to the replicator equation [92,93] which is widely used in modelling biological, cultural, and social processes (see the electronic supplementary material).

2.3. Utility function

Following earlier work (e.g. [94–98]), we define the utility function as the sum of a material and normative components. For a non-dominant faction,

$$u_i(x_i) = R_i(x_i) + [\eta_0 x_s + \eta_1(2\tilde{x} - 1)]x_i, \qquad (2.4a)$$

where η_0 is the normative value of allegiance to the state (embodied in the most powerful faction which makes effort x_s) and η_1 is the value of conformity with the majority of peer factions (among which the average effort is $\tilde{x}$). Parameter η_0 can also be viewed as a measure of the legitimacy felt towards the most dominant faction or the ruling regime. For the dominant faction,

$$u_s(x_s) = R_s(x_s) + \eta_0 x_s, \tag{2.4b}$$

that is, the state faction has a normative value η_0 of contributing to production.

The two main components of our utility function are material payoffs and the effects of social influences. These are the main forces driving human behaviour as studied by the two most commonly used mathematical theories in social sciences: game theory [93,99–101] and social influence theory [102–107]. Our approach unifies them in a single framework leading to more realistic and comprehensive models [76,96–98,108–110]. We separate social influences into peer influences and the authority/state influence because these two types of influence have different nature and power [75,97,98,111–115].

2.4. Strategy update

We will assume that each faction updates its action in the economic game, that is, chooses x_i value, randomly and independently with probability ν. Assuming bounded rationality [116], we postulate that each updating faction uses myopic best response to maximize its utility u_i. To capture errors in decision-making, which are unavoidable in any realistic situation, we use the Quantal Response Equilibrium approach with logit error [117]. The corresponding mathematical model has a non-negative precision parameter λ (see the electronic supplementary material). If $\lambda = 0$, the factions cooperate or defect with equal probabilities; if $\lambda \to \infty$, the factions always use the best strategy. We will also assume that factions pay a fixed cost δ for changing their action (i.e.moving between the elite and counter-elite).

2.5. Intuitions

The behaviour of the two main components of our model, the economic game and the political game, is well understood when each is acting in isolation. In particular, if the factions' power f is fixed, the society will split into high-power factions that cooperate and low-power factions that defect [118]. Similarly, the existing theory of the replicator equation, which describes selection of the 'strongest' among many competitors, tells us that if the factions' resources R are fixed, then over time all power will concentrate on just one faction. What is not well understood, however, is how these components work in tandem, i.e. condensation of power versus the fractionation of cooperation. Below we study what happens when both resources and power change dynamically as a result of bounded rational decision-making processes involved in the economic and political games.

3. Theoretical results

3.1. Basic model

Consider first a basic model with equal initial power ($f_i = 1/n$ for all i), no normative values ($\eta_0 = \eta_1 = 0$), no variation in endowment ($R_i = R_0$ for all i), and no natural resource to divide among the elites ($E = 0$). The electronic supplementary material provides some analytical results for this model. We focus here on the results of agent-based simulations of the more interesting cases. We will assume that all factions cooperate initially and, to reduce the effects of stochasticity, will postulate infinite precision initially ($\lambda = \infty$).

3.1.1. Three dynamic regimes

Numerical simulations show that in the basic model there are only three possible dynamics: complete loss of cooperation, stable hierarchy, and continuous turnover. Under complete loss of cooperation and production, all factions have similar power. Under stable hierarchy, one faction persists on top of the hierarchy with some fluctuations in the power and identities of the elites and counter-elites. Under continuous turnover of dominant factions, cycles of cooperation and defection are coupled with cycles in power and inequality. The regimes of stability and turnover are illustrated in figures 1*a*,*c*, 2*a*,*c* and 1*b*,*d*, 2*b*,*d*, respectively. The top graph in each set shows which factions cooperate and which do not at each time, and how coordinated these actions are. The solid segments of black and white strips correspond to periods of apparent stability in the society [62]. During these periods, inequality nevertheless keeps growing (as shown in the two other parts of each set).

3.1.2. Effects of parameters

The first regime is expected when the benefit b of cooperation is small, collective goods are difficult to produce (half-effort parameter x_0 is large), and the number of factions n is large. The second regime is expected when the benefit b of cooperation is large, collective goods are easy to produce (half-effort parameter x_0 is large), and the number of factions n is small. The third regime is expected at intermediate values of b, n and x_0.

Figure 3 illustrates the effect of changing parameters on long-term average behaviour of the model. Figure 3*a* shows the average number of contributing factions (which is zero in the lower left because there is no cooperation). Also the proportion of contributing factions (and, thus, the total level of production) is reducing with the number of factions n. Figure 3*b* shows that the average power of the most dominant factions increases with b and decreases with n. The incumbency parameter ε does not affect the average level of cooperation or the power of the most dominant faction. Figure 3*c* characterizes the turnover of the most dominant factions observed during the simulation run. We measured the turnover using the Simpson index, which is the number of dominant factions during the simulation run appropriately weighted by the time they were in power (see the electronic supplementary material). This number is equal to 1 in the top right part of the graph where the dynamic regime (ii) out of three is observed. Significant turnover of dominant factions (i.e. regime (iii)) is observed along the diagonal of figure 3*c*. Even in the absence of turnover of the dominant factions, there can be significant fluctuations in the power of factions and production levels. The effects of parameters on the period of fluctuations in the power of the most dominant faction are illustrated in figure 3*d* (see electronic supplementary material for how period was estimated). Note that increasing incumbency parameter ε decreases the period of fluctuations in power in regime (ii) and increases the turnover of dominant factions in regime (iii).

3.1.3. Cycling

To shed more light on social volatility and the dynamics of cycling in cooperation and inequality we focused on the

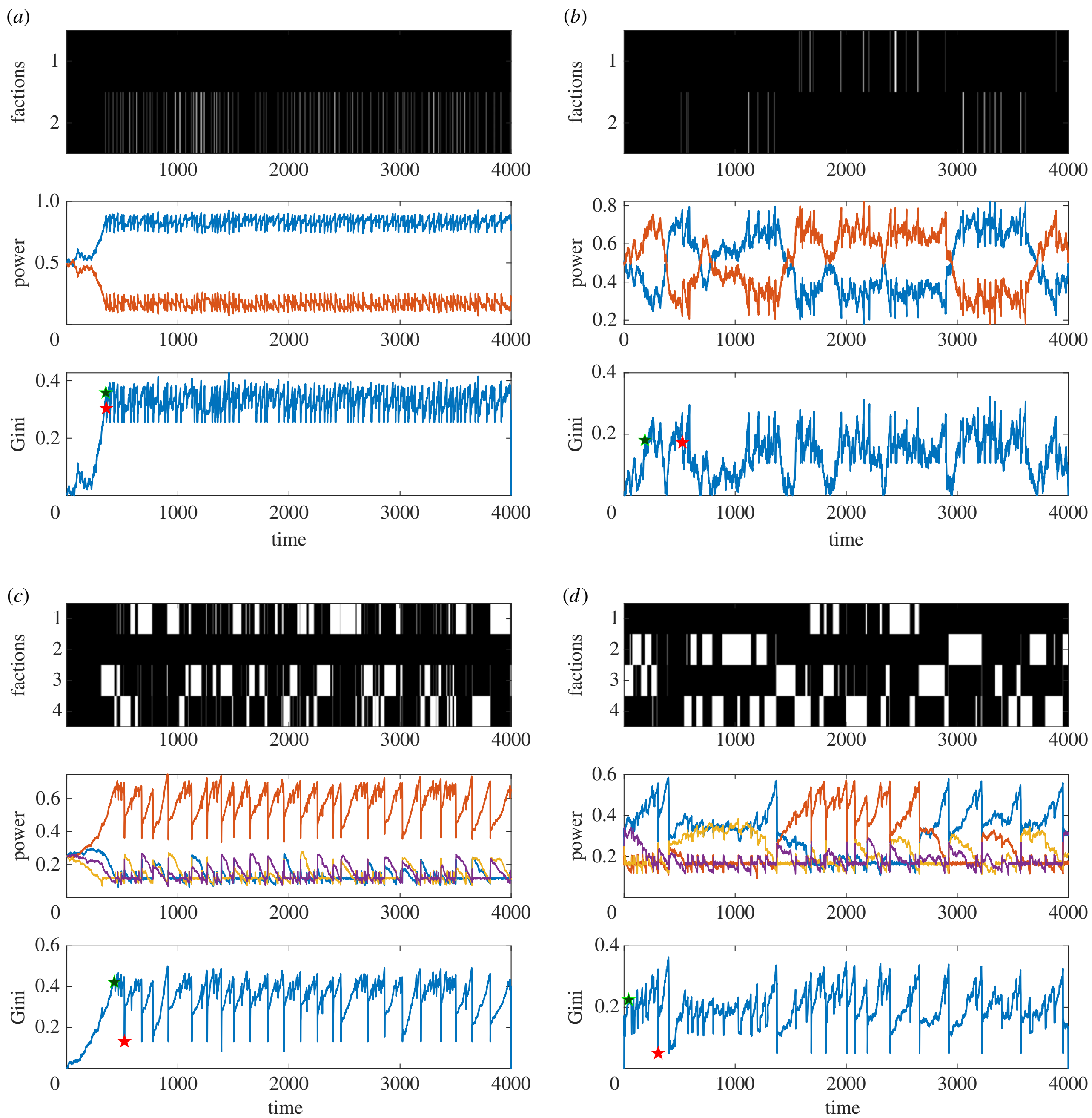

Figure 1. Examples of social dynamics in the basic model: with no turnover (*a*,*c*) or with turnover (*b*,*d*) of the most dominant factions. In each set of graphs, top graph: factions cooperating at time *t* are shown as black pixels, defecting factions as white pixels; middle graph: different colours show power f_i of individual factions; bottom graph: dynamics of Gini index based on the resources R_i. (The Gini index based on power exhibits very similar dynamics.) The red stars mark the first collapse of cooperation at time *T* (when *X* hits 1 for the first time). The green stars mark the end of the transient period τ (explicitly defined in subsection 'Cycling'). Other parameters: $x_0 = 0.75$, $\kappa = 2$, $\delta = 0.25$, $\gamma = \eta_0 = \eta_1 = r = 0$. (*a*) $n = 2$, $b = 10$, $\varepsilon = 0.03$. (*b*) $n = 2$, $b = 5$, $\varepsilon = 0.01$. (*c*) $n = 4$, $b = 15$, $\varepsilon = 0.03$. (*d*) $n = 4$, $b = 10$, $\varepsilon = 0.03$.

first cycle, i.e. starting with complete cooperation at $t = 0$ and ending with its 'collapse' at time *T* defined as the time when *X* becomes ≤1. We also compute the duration of the initial cooperative phase τ during which inequality grows but cooperation remains high and stable (see figure 1 and the electronic supplementary material). The parameter τ was defined as the time to reach for the first time the long-term average value of the Gini index. Considering the model dynamics on longer time-scales over multiple cycles is less informative because in most realistic situations the nature and the number of factions as well as various forces captured by the model parameters are likely to change with each new cycle. Figure 4 illustrates the effects of parameters *n*, *b* and ε plus one additional parameter on τ (figure 4*a*) and *T* (figure 4*b*,*c*,*d*). Increasing incumbency ε, decreasing the number of factions *n*, and decreasing the benefit *b* accelerate the collapse of cooperation.

3.2. Additional factors

Next we consider several additional factors. To isolate their effects, we add only one new factor at a time. The red lines in figure 4 show the values for the basic model with the additional parameter set to 0; the green and blue lines correspond to two different positive values of the corresponding parameter.

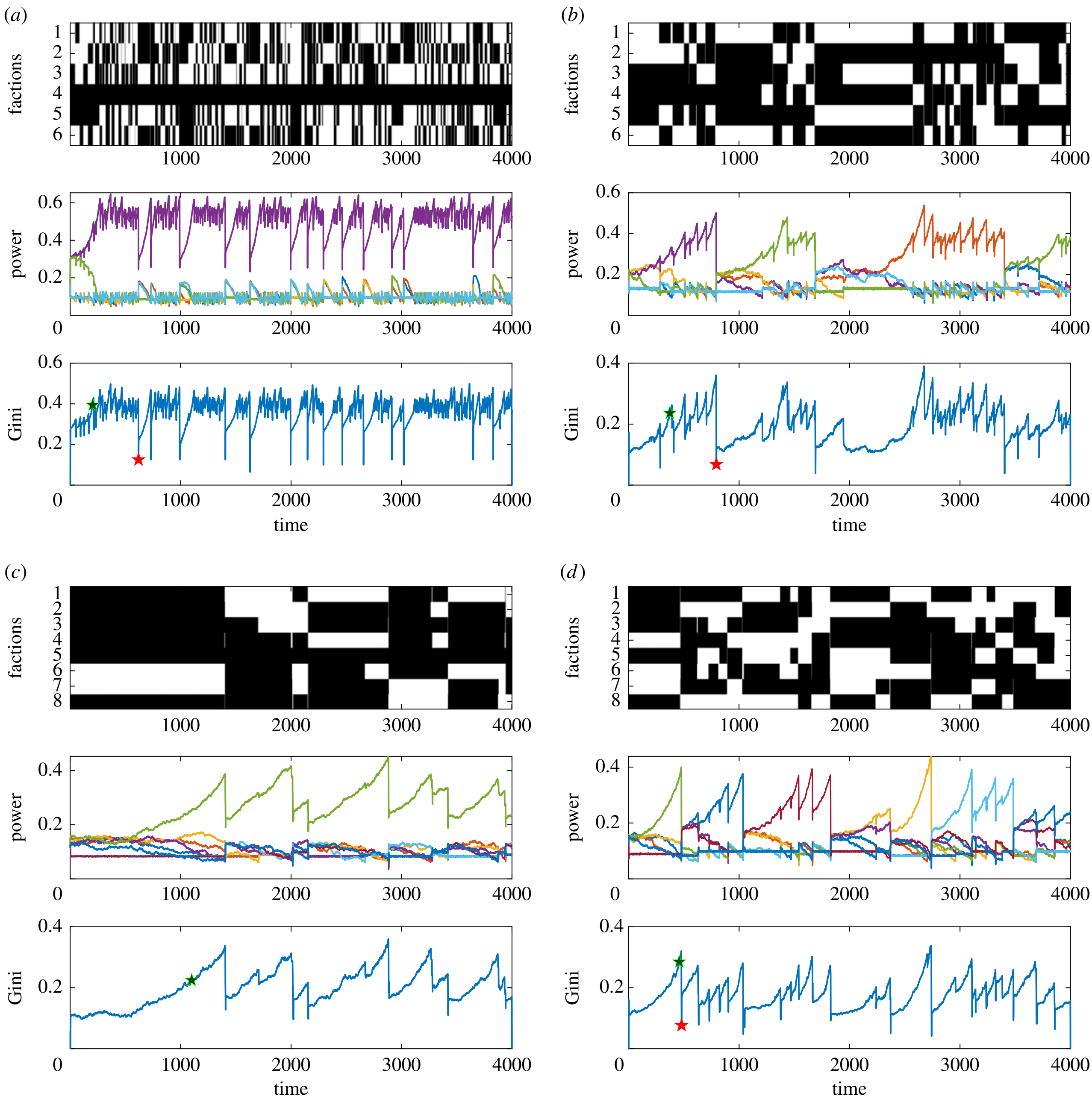

Figure 2. Same as in figure 1 but with $n = 6$ and 8. (*a*) $n = 6$, $b = 15$, $\varepsilon = 0.05$. (*b*) $n = 6$, $b = 15$, $\varepsilon = 0.03$. (*c*) $n = 8$, $b = 20$, $\varepsilon = 0.01$. (*d*) $n = 8$, $b = 20$, $\varepsilon = 0.03$.

3.2.1. Effects of initial variation in power

In figure 4*a*, the additional parameter $0 \leq \gamma \leq 1$ characterizes the initial variation in power. With $\gamma = 0$, each faction has an equal power $1/n$ initially; with $\gamma = 1$, the initial distribution of power is drawn from a 'broken stick' distribution (see the electronic supplementary material). As expected, increasing incumbency ε and/or initial power inequality γ shorten the initial cooperating phase τ. The effects of γ on T are insignificant (not shown).

3.2.2. Effects of the strength of allegiance to the state and conformity

Figure 4*b* shows that increasing the normative value η_0 of allegiance to the state increases the stability of the system and can often prevent its collapse (on the time scale studied, e.g. with $n = 8$). However, conformity with the majority of peer factions η_1 accelerates the collapse of cooperation (figure 4*c*). This happens because once a majority of low-power factions are defecting, the other factions are 'pulled' to defect as well. This effect is only present when the number of factions is not too small.

3.2.3. Effects of collectively owned resource

Finally, we consider the effects of a collectively owned resource E available to sharing among the elites which is independent of the extent of their cooperation. We write its amount as $E = r \times b$, where r is a new parameter measuring the amount of this benefit relative to the maximum amount nb that can be produced by collective action. Figure 4*d* shows that r has a nonlinear effect on T. If cooperation can potentially bring large benefits (e.g. with $b = 15$ or 20 and $n = 6$ or 8), increasing r decreases T. That is, high natural resources disincentives cooperation—a phenomenon called the 'resource curse' [119]. If the

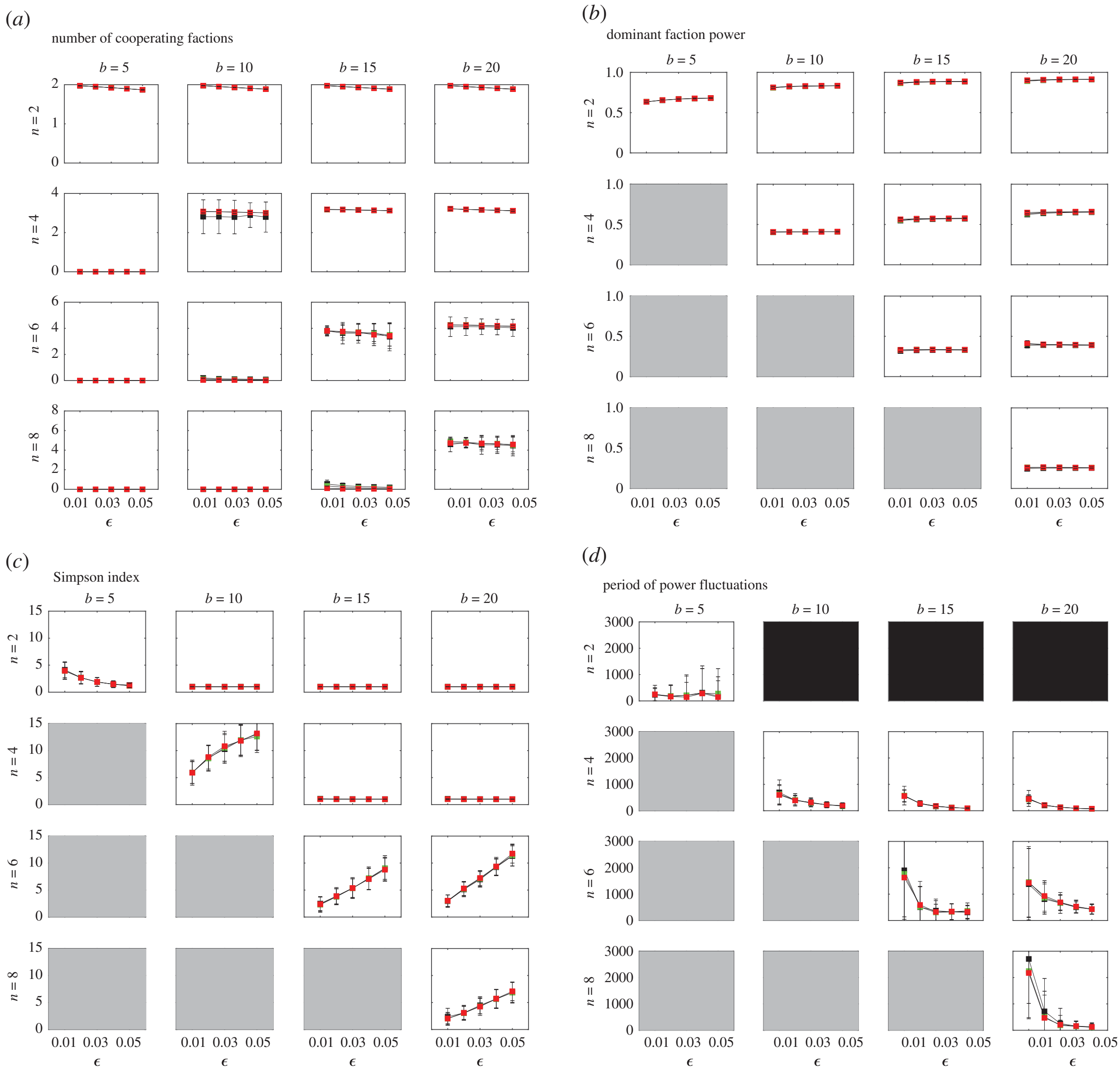

Figure 3. Long-term average values of (*a*) the number of contributing factions, (*b*) power of the dominant faction, (*c*) an effective number of different dominant factions, and (*d*) the period of fluctuations in power. For parameter values corresponding to the grey graphs, there are no contributing factions. For parameter values corresponding to the black graphs, fluctuations in power are insignificant. Baseline parameters: $c = 1$, $x_0 = 0.75$, $\delta = 0.25$, $\kappa = 2$, $\lambda = \infty$, $\nu = 0.5$, $\gamma = 0.0$, $\eta_0 = 0$, $\eta_1 = 0$, $r = 0$. The averages and confidence intervals over 200 runs each of length 4000 time steps.

potential benefits of cooperation are not high enough, however, increasing r increases T because some factions are motivated to cooperate with the state to receive their share of resources.

3.2.4. Effects of the inequality in endowments

Introducing inequality in endowments R_0 results in a possibility of new dynamics: stable cooperation of high-endowment factions with low-endowment factions not contributing at all or exhibiting cyclic or stochastic dynamics (see figure S1 in the electronic supplementary material for an example). Introducing errors in the decision-making process (that is, decreasing precision parameter λ) increases stochasticity of the system without affecting the results qualitatively (see the electronic supplementary material).

3.2.5. Theoretical predictions

Our modelling results thus lead to a number of predictions:

1. Horizontal inequality should increase when cooperation between groups is high (generating large amounts of resources).
2. By coupling economic and political power, a strong incumbency effect ε (weak rule of law) should increase horizontal inequality.
3. Horizontal inequality should increase social unrest and accelerate the collapse of cooperation (shorter T).
4. High normative value η_0, i.e. support for the state's institutions, will tend to stabilize cooperation (longer T).
5. High normative value η_1, i.e. conformity, should, counter-intuitively, destabilize cooperation (shorter T).
6. Increasing the number of factions should decrease cooperation and increase turnover of dominant factions and/or oscillations in power and production.
7. High initial inequality in power should decrease stability.
8. Variation in faction-specific endowments, R_0, should increase resilience of the society to high inequality.

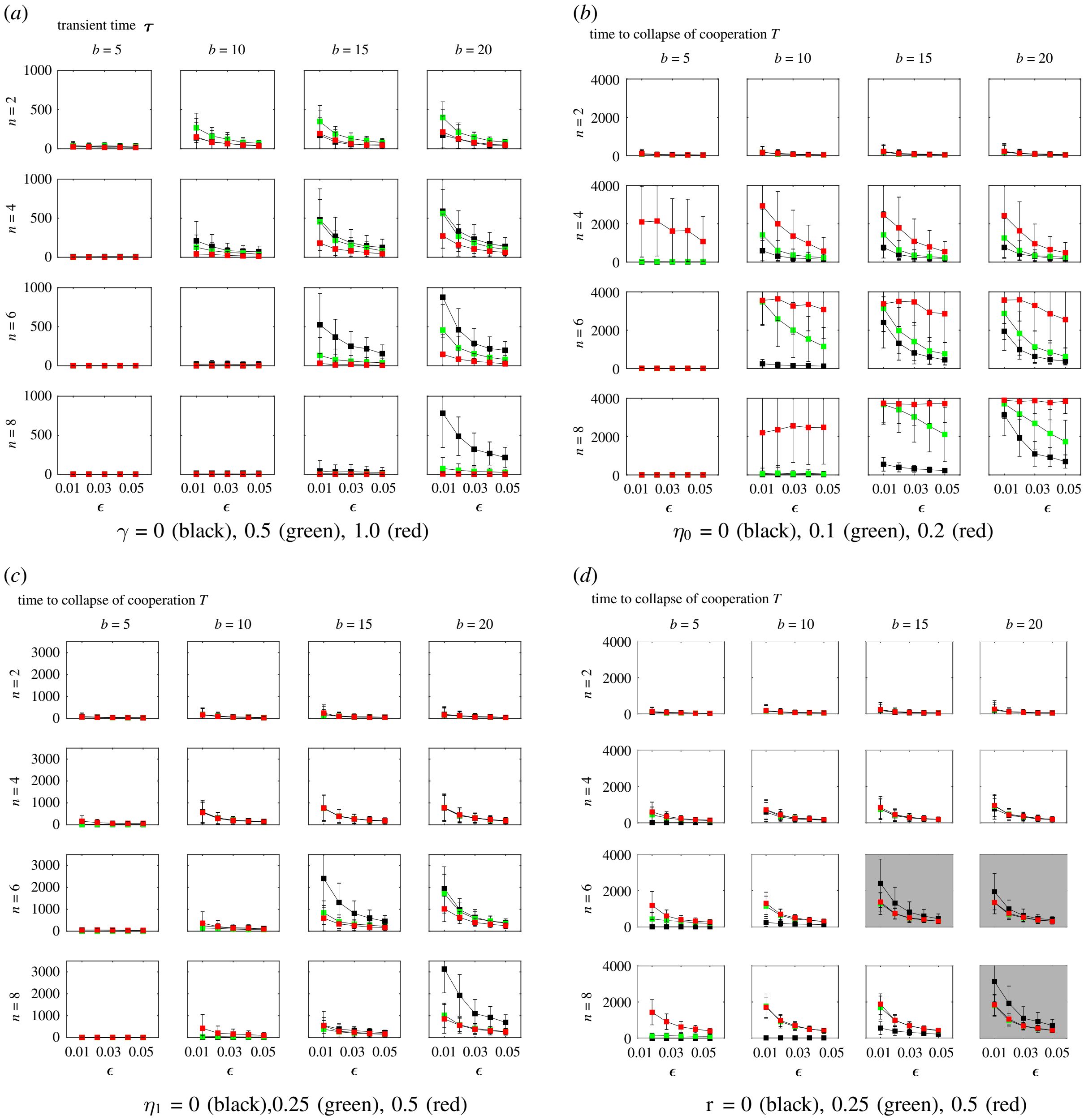

Figure 4. The duration of the transient phase τ (*a*) and the time to the collapse of cooperation T (*b–d*) as affected by the number of factions n, benefit b, incumbency ϵ, and one extra parameter. The additional parameter is: (*a*) initial power inequality γ; (*b*) allegiance to the state η_0; (*c*) conformity with peers η_1; (*d*) extra resource r. In the shaded graphs in (*d*), the effect of r on T is opposite to that in the white graphs. Baseline parameters: $c = 1$, $x_0 = 0.75$, $\delta = 0.25$, $\kappa = 2$, $\lambda = \infty$, $\nu = 0.5$, $\gamma = 0.0$, $\eta_0 = 0$, $\eta_1 = 0$, $r = 0$. The averages and confidence intervals over 200 runs each of length 4000 time steps. (*a*) $\gamma = 0$. (*b*) $\eta_0 = 0$. (*c*) $\eta_1 = 0$. (*d*) $r = 0$.

9. The presence of additional resources r not dependent on cooperation (e.g. natural resources, state rents) should decrease cooperation.

4. Empirical analysis

4.1. Data and methodological approach

This section looks at the empirical evidence in favour of hypotheses 2–6. We focus on hypothesis 3, on the effect of economic horizontal inequality on social unrest. The unit of analysis is the country-year and the main sample covers more than 1800 observations on 75 countries between 1991 and 2016.

The model describes the process through which horizontal inequality leads to the breakdown of cooperation between factions. It, therefore, corresponds more closely to mild forms of violence that are spontaneous and require minimal organization. We thus focus on small-scale forms of conflict. Our dependent variables capture six forms of social unrest: riots, strikes, assassinations, anti-government demonstrations, guerrillas and revolutions. With the partial exception of guerrillas and revolutions, all of these represent relatively small-scale forms of conflict.

The main dependent variable (*Unrest Index*) is an index that gives how many of these six forms of social unrest a country has experienced within a given year. For example, if country A has experienced a riot and a strike in year 2005, but not an assassination, a demonstration, a guerrilla or a revolution, it receives a score of 2. This variable ranges between 0 and 6.

The measures of riots, strikes, assassinations, anti-government demonstrations, guerrillas and revolutions are taken from Banks' dataset [120] (see the electronic supplementary material, for definitions). These variables count the number of riots, etc., that a country has experienced within a given year. To compute the *Unrest Index*, we recode the variables as six dummy variables that take the value one if a country experiences at least one riot, etc., in a year. We then add them.

We also run models on these six dummy variables. For example, in one of the models, we estimate the effect of horizontal inequality on the probability that a country experiences at least one riot within a given year. We recode the variables as dummy variables—rather than use the original continuous variables—to make sure that the results are not driven by outliers that have experienced a large number of riots, etc. We show in electronic supplementary material, table S5, that the results are largely unchanged when we employ the continuous variables instead.

Our key independent variable is economic horizontal inequality. It is a Gini coefficient that captures inequality between ethnic groups based on luminosity data and ethnic group definitions from Ethnologue [9]. In the electronic supplementary material, we show that the results are largely robust to the use of two alternative measures of horizontal inequality (electronic supplementary material, tables S6 and S7). The model describes the consequences of inequality between factions. Of course, ethnicity is only one of multiple possible ways in which factions can be defined. For practical reasons, we had to focus the empirical analysis on a single type of faction. Therefore, the sample only covers countries in which ethnicity is politically relevant according to the Ethnic Power Relations dataset [121]. In the electronic supplementary material, we show that the results are largely unchanged when we include all countries, regardless of whether or not ethnicity is politically relevant (electronic supplementary material, table S4).

We use rule of law [122] as an empirical proxy for incumbency because one function it serves is to ensure politically powerful elites must obey the same rules as everybody else [123], thus opportunities to convert political power into economic power are reduced. The two cultural norms—support for institutions and conformity—are composite variables of relevant World and European Values Survey (WEVS) items (see electronic supplementary material). Support for institutions is comprised of survey items asking if people have confidence in the government, political parties, civil service, armed forces, press and police. Conformity is the reverse of the well-established ‘autonomy index’ [124], where low conformity nations value traits like independence and determination and high conformity nations value obedience and religious faith. We use principal component analysis to compress these multiple items into one-dimensional measures for both ‘support for institutions’ and ‘conformity’. Support for institutions captures the beliefs that underlie the norm for ‘conformity with the state’ in our model. Likewise, a tendency to conform (and not act autonomously) captures the belief system that underlie the model’s ‘conformity with peers’ parameter. Finally, we measure the number of factions using the country’s number of politically relevant ethnic groups taken from the Ethnic Power Relations dataset [121]. Table 1 lists the proxies used for the key model parameters.

The analysis controls for variables usually included in studies of small-scale conflicts: dummy variables for former British and French colonies, polity score and polity score squared, ethnic fractionalization [121], GDP *per capita* logged and the growth rate [125]. We include the Polity score squared because the previous literature finds that partial democracies (i.e. countries with intermediate polity scores) are more likely to experience political violence [126].

Table 1. Proxy measures for model parameters.

model variable or parameter	its proxy in data
Gini index for payoffs	horizontal inequality [9]
time to collapse of cooperation T	social unrest [120]
incumbency ε	rule of law [122]
allegiance to the state η_0	support for institutions [12,13]
conformity with peers η_1	conformity [12,13]

A limitation with cross-cultural studies like ours is Galton’s problem: countries with shared cultural histories will not be fully independent in terms of other measures [127–129]. Whereas language phylogenies have often been used as a proxy for cultural proximity [128,129], this approach would not be appropriate for our framework because our units of cultural groups are ethnic groups, which often have different languages and other cultural attributes.

Instead, we focus on geographical proximity. Countries that are neighbours, for example, are likely to have many of the same ethnic groups. Moreover, the previous literature has shown that political unrest often diffuses across neighbours [130]. To account for spatial diffusion, we construct a variable, *Spatial DV*, which gives the average social unrest level of the country’s neighbours within a given year. This variable is constructed for each dependent variable (*Unrest Index*, *Riot*, etc.). For example, if a country has three neighbours, the *Spatial DV* in the models in which the dependent variable is *Unrest Index* is the average *Unrest Index* score of these three countries. In the models using *Riot*, it is the proportion of them that have experienced at least one riot during that year. Neighbours are defined as countries that share a land border or that are separated by a stretch of water less than 400 miles (data taken from the Correlates of War Project [131]). We present the data used to measure the important quantities in detail in the electronic supplementary material. Electronic supplementary material, table S3, shows basic descriptive statistics.

All models are estimated in *STATA*. The models in which the dependent variable is *Unrest Index* are estimated using ordinary least squares (command *reg* in *STATA*). The models with the riot, strike, assassination, demonstrations, guerrilla and revolution dummy variables are estimated using Probit models (command *probit* in *STATA*). All models include lagged dependent variables. Therefore, we employ dynamic models, in that they capture the association between the explanatory variables and changes in social unrest. In order to address temporal autocorrelation, in all models standard errors are clustered by country (using the command *cluster*) [132]. This enables us to account for the fact that observations from the same country at different points in time are not independent from one another. We present other tests/diagnostics of temporal autocorrelation in the electronic supplementary material (tables S10 and S11).

Unfortunately, the data do not enable us to test the cycling relationship implied by the model. Ideally, we would have an exogenous time-variant instrument for horizontal inequality that we could use in two stage estimations. However, we are not aware of any instrument for horizontal inequality that is exogenous to social unrest. Some authors have used the ratio of land suitable for sugar production and wheat production as an instrument for vertical inequality [133]. Countries with more land suitable for sugar production have tended to be more unequal historically than those that produce wheat. There are at least three problems with using the sugar-to-wheat land ratio in this study: (i) it is an instrument for vertical inequality, not horizontal inequality; (ii) it fails the exogenous requirement—land endowment affects social unrest through mechanisms other than horizontal inequality; and (iii) it is not time-variant, so it would not enable us to test the cycling relationship implied by the model.

In fact, there is virtually no variation in horizontal inequality within the relatively short period under study (25 years), which makes it difficult to test the cycling relationship. There are two reasons why measures of horizontal inequality show little within-country variation. First, the data are imperfect. The main measure is based on inequality in luminosity between regions inhabited by different ethnic groups, which does not change much in time.

Second, and perhaps more importantly, inequality is highly sticky within countries over time [19,134]. Apart from the dynamics described by our model, most other explanations for changes in inequality go back to major events such as major wars, the way different countries have been colonized, the political institutions that were in place, for example, in the middle age, resource endowment, etc. Short of major events, inequality (vertical and horizontal) does not change much in the short run. Houle [83], for example, constructs a measure of horizontal inequality using survey data covering more than 20 years. This measure also changes very little across survey-waves (which are conducted in different years) within the same countries, even though each survey-wave relies on different respondents. Even major events rarely have an immediate effect on inequality. For example, transition from autocracy to democracy has been found to only affect inequality in the very long run, notably because most of its effect operates through educational opportunities, which only translate into income changes once individuals have completed their education [135].

Therefore, we believe that the dynamic relationship implied by the model operates in the long run, while our data only enable us to look at the correlation between horizontal inequality and social unrest in the short run. This empirical analysis thus only presents correlational support for the predictions and mechanisms implied by the theoretical model. We cannot be sure that our results are not driven by some form of endogeneity between social unrest and the explanatory variables of interest, particularly horizontal inequality. At the same time and as we have noted, horizontal inequality is highly sticky within countries within the short time period of our data. This suggests that most of the correlation between horizontal inequality and social unrest is driven by horizontal inequality, rather than the other way around.

In fact, most previous studies on horizontal inequality and social unrest use an estimation strategy similar to ours and many assume that horizontal inequality is unchanged over several decades [38,81–83]. Thus, although our empirical approach has limitations, it is consistent with the literature.

Not only does the lack of within-country variation make it difficult to use techniques such as instrumental variable estimation, but it also prevents us from including country fixed effects. Moreover, regardless of within-country variation, country fixed effects would not be optimal in small time panels like ours [136] and the inclusion of both country fixed effects and lagged dependent variables creates bias, known as the Nickell bias [137].

4.2. Empirical results

Our main results are shown in table 2. All models report robust standard errors clustered by country. Consistent with hypothesis 3, we find that horizontal inequality is positively correlated with *Unrest Index*, riots, revolutions and anti-government demonstrations. The coefficients on assassinations, strikes and guerrillas are of the (positive) predicted sign, but are not statistically significant.

Figure 5 illustrates the magnitude of the associations for each dependent variable. The first panel gives the predicted *Unrest Index* score across horizontal inequality values. The six other panels give the predicted probability that a given country experiences at least one riot, etc., across all horizontal inequality levels. All other explanatory variables are kept at their median. For example, the predicted *Unrest Index* score of a country with a horizontal inequality value at the 10th percentile of the distribution (0.165) is 0.97, while the predicted score of an identical country with a horizontal inequality value at the 90th percentile (0.888) is 1.289. Importantly, these predicted values give differences within a *single year*. In the long run, we would thus expect countries with high horizontal inequality levels to be cumulatively more unstable than the latter.

The electronic supplementary material reports multiple robustness tests of the association between horizontal inequality and social unrest. Specifically, the results are largely robust when we: (i) extend the sample to countries in which ethnicity is not politically relevant (electronic supplementary material, table S4); (ii) use a different operationalization of the dependent variables (electronic supplementary material, table S5); (iii) use alternative measures of horizontal inequality (electronic supplementary material, tables S6 and S7); (iv) omit countries with horizontal inequality values at either extremes (electronic supplementary material, tables S8 and S9); and (v) employ alternative strategies to address temporal autocorrelation (electronic supplementary material, tables S10 and S11).

On balance, we also find evidence consistent with hypotheses 2, 4 and 6: countries with robust rule of law (hypothesis 2) are more stable, while those with higher conformity values (hypothesis 4) and more factions/ethnic groups (hypothesis 6) are more unstable. To our knowledge, we are the first to document a positive association between conformity values and political unrest. The association between the number of ethnic groups and unrest is also interesting given that ethnic and religious fractionalization has been found to bear no relationship with political violence [84]. The evidence in favour of hypothesis 5 is much weaker as we fail to find any significant correlation between respect for institutions and unrest. Although never statistically significant, for some forms of unrest—such as

Table 2. Determinants of social unrest. All models are run with *STATA*. Model 1 is run using ordinary least squares (with the command *reg*) and models 2–7 using Probit estimations (with the command *probit*). All independent variables are lagged. Robust standard errors clustered by country in parentheses.

	dependent variables						
	index	riot	assass.	strike	guerrilla	revol.	demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
lagged DV	0.492	0.964	1.005	0.946	1.731	1.797	0.735
	(0.032)***	(0.092)***	(0.100)***	(0.135)***	(0.126)***	(0.147)***	(0.079)***
spatial DV	0.203	0.972	0.593	1.115	0.390	−0.209	0.813
	(0.040)***	(0.153)***	(0.244)**	(0.256)***	(0.305)	(0.218)	(0.149)***
horizontal inequality	0.441	0.507	0.232	0.363	0.478	0.614	0.551
	(0.148)***	(0.188)***	(0.234)	(0.256)	(0.302)	(0.251)**	(0.195)***
rule of law	−0.187	−0.216	−0.298	−0.022	−0.203	−0.139	−0.176
	(0.063)***	(0.098)**	(0.096)***	(0.117)	(0.099)**	(0.092)	(0.079)**
conformity	0.229	0.049	0.256	0.263	0.418	0.338	0.252
	(0.109)**	(0.141)	(0.151)*	(0.205)	(0.177)**	(0.181)*	(0.131)*
respect for institutions	−0.014	−0.010	−0.151	−0.030	0.216	0.170	−0.118
	(0.093)	(0.144)	(0.134)	(0.216)	(0.160)	(0.134)	(0.115)
number of groups	0.018	0.015	0.018	0.012	0.018	0.004	0.034
	(0.005)***	(0.009)*	(0.009)*	(0.008)	(0.007)***	(0.009)	(0.005)***
former British colony	.069	0.266	0.229	0.324	−0.075	−0.274	0.125
	(0.126)	(0.153)*	(0.150)	(0.177)*	(0.192)	(0.194)	(0.159)
former French colony	.012	0.023	0.067	0.104	0.179	−0.083	−0.122
	(0.081)	(0.092)	(0.220)	(0.173)	(0.182)	(0.156)	(0.113)
polity score	.017	0.011	0.035	0.044	0.020	0.004	0.011
	(0.007)**	(0.011)	(0.011)***	(0.013)***	(0.012)*	(0.011)	(0.009)
polity score squared	−0.002	−0.002	−0.002	−0.0001	−0.004	−0.002	−0.003
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
ethnic fractionalization	−0.082	0.010	−0.317	−0.502	0.012	−0.118	−0.209
	(0.155)	(0.235)	(0.241)	(0.326)	(0.281)	(0.253)	(0.208)
GDP *per capita* (logged)	0.189	0.231	0.049	−0.015	0.239	−0.101	0.330
	(0.049)***	(0.071)***	(0.077)	(0.089)	(0.074)***	(0.076)	(0.063)***
growth	−0.005	−0.003	−0.011	−0.008	−0.0002	−0.010	−0.011
	(0.003)	(0.005)	(0.006)*	(0.008)	(0.008)	(0.005)**	(0.005)**
N	1889	1889	1889	1889	1889	1889	1889
log-Lik.	−2699.511	−862.001	−580.783	−547.316	−517.109	−451.489	−1035.998

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

assassinations—respect for institutions is indeed related with less instability. However, it is positively correlated with other forms of instability, such as guerrillas.

As expected, political instability among neighbours is usually associated with political instability at home. There are several mechanisms that could drive this correlation. As discussed above, political instability may diffuse across neighbours. Moreover, neighbours may share a common culture, which makes them likely to experience similar forms of social unrest. Finally, neighbours may share similar characteristics, such as economic structures or dependence on international superpowers, which renders them vulnerable to the same political and economic shocks. Although the variable *Spatial DV* is too broad to distinguish different mechanisms, it serves as a control for spatial autocorrelation and shared cultural histories, enabling estimation of the association between horizontal inequality and political unrest.

4.3. Discussion

Recent discussions, supported by data analysis, have identified economic, social, and political inequality between identity groups as a possible threat to the stability of society [5,16–19,21,24,35–39,81–83]. Here we have modelled cooperation and conflict in a society composed of multiple factions engaged in economic and political interactions. We explicitly assumed that politically powerful factions are attempting to shape the rules of economic interactions to

royalsocietypublishing.org/journal/rsif *J. R. Soc. Interface* **19**: 20210725

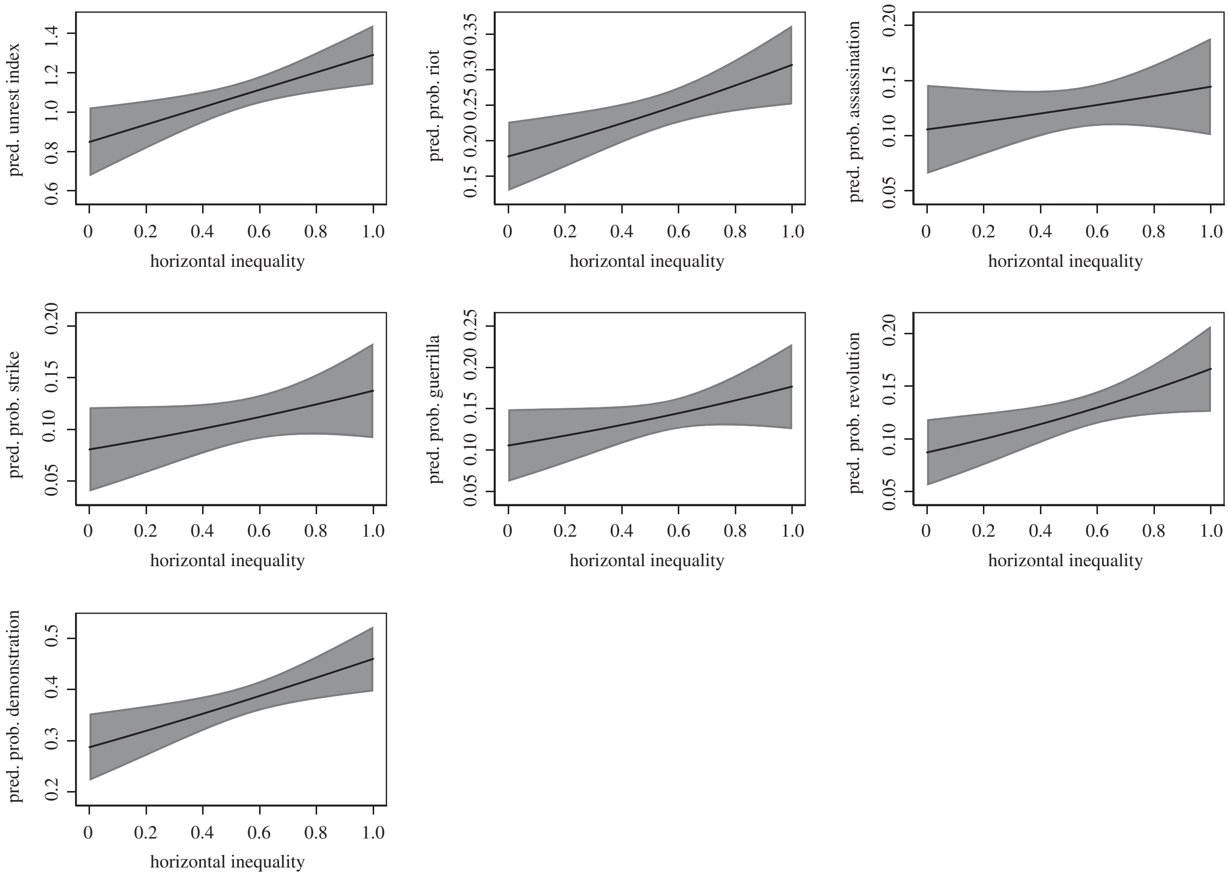

Figure 5. Effect of horizontal inequality on the predicted probability that a country experiences social unrest in a given year. Shaded areas represent 95% confidence intervals.

their own advantage. Our model showed how inequality arising among factions that otherwise wish to cooperate led to conflict, at least until new elites emerged in the model's dynamic cycle. Our model captures the effects of rule of law, social norms of support for the state and conformity with peers. It also makes predictions regarding the effects of the number of factions in the society, initial inequality in power, heterogeneous endowments and resources, and the presence of additional resources available for redistribution among the elites independently of the success of collective action.

Our work represents the first attempt to mathematically model the effects of horizontal inequality on social dynamics. Our models include a number of factors which are firmly established as crucial drivers of human decision-making but nevertheless have not received due attention in the literature on horizontal inequality. More generally, we have expanded the theoretical tool kit of evolutionary game theory by developing a novel approach in which agents are engaged in two separate games: an economic game about material resources and a political game about the power to set the rules of the economic game. While earlier work used static or statistical models, our inherently dynamic approach shows how the growth in inequality and breakdown in cooperation develop in time. Our model is thus able to predict relevant time scales rather than just the direction (positive/negative) of various effects. An interesting feature of the joint dynamics of cooperation and inequality revealed by our model is their inherently cyclic behaviour (as illustrated in figures 1 and 2).

The model predicts that growing inequality tends to lead to the collapse of cooperation between factions, which could then trigger conflict. This process can be impeded by several mechanisms. One is the decoupling of political and economic power through rule of law, which prevents a 'power grab' leading to dangerous levels of inequality. Our model indicates, that a social norm for allegiance to the state also delays factional conflict, whereas a social norm for conformity with other factions hastens the onset of conflict by facilitating a cascade of defections. Division of the society into multiple factions decreases its stability. One additional mechanism is heterogeneity in endowments between the factions, which makes societies more stable to the negative effects of inequality by giving incentives to powerful factions to cooperate with the state. The availability of certain material resources that can be acquired by the state without cooperation with other factions makes societies less stable (resource curse).

We tested some of the predictions of the theoretical model using country-year data from 76 countries between 1991 and 2016. Our main finding is that, consistent with our model, horizontal inequality is associated with social unrest, which we employ as a proxy for the breakdown of cooperation between factions. With the exception of the predicted association between respect for institutions and political instability, the evidence is consistent with the core predictions made by the model.

Although our results are very encouraging, there are a number of data-related considerations for future work. First, and perhaps most importantly, the current horizontal inequality data do not enable us to access the direction of the causality in the relationship between horizontal inequality and political instability. As noted above, we believe that, since inequality (including horizontal inequality) is highly sticky within countries, the relationship captured in our analysis is mainly driven by the effect of horizontal inequality on instability within the short period of time we study. However, having horizontal inequality data for longer periods of time would enable one to better capture the nature of the relationship. To be clear, this limitation is shared by almost all previous large-*N* quantitative studies of horizontal inequality and political violence, although in our case it prevents us from testing the cycling relationships predicted by the model. Developing horizontal inequality data spanning longer time periods should thus be a priority for future work.

Second, we do not have ideal measures for all variables included in the model. Most notably we use rule of law as a proxy for the decoupling of economic and political power. However, the rule of law is probably too broad because it serves a number of different functions. For example, the rule of law may promote a dynamic private sector economy, which in turn would decrease political instability. This relationship is not directly captured by the model.

Our modelling work adds to the general knowledge on the relationship between horizontal inequality and instability in a number of ways. First, it provides a general framework for describing the dynamics of this relationship. It also characterizes the importance of economic, cultural and social factors, including legal checks and balances, cultural allegiance to the state, and conformity which are factors not commonly emphasized in the literature on horizontal inequality. Our model makes quantitative predictions about the effects of parameters on various characteristics including the time-scales involved.

On the empirical side, we tested several hypotheses emerging from interpreting our modelling results. We make two main empirical contributions. First, we test the association between horizontal inequality and low-scale conflicts, rather than complex conflicts such as civil wars or coups. Our theoretical model is more closely related to low-scale conflicts because it focuses on the breakdown of cooperation between factions. The second contribution is that we assess novel culture-based hypotheses, notably regarding the role of social norms like conformity and institutional confidence.

It is well established in the cross-national quantitative literature that ethnic fractionalization is statistically unrelated to the probability of political violence, regardless of whether one looks at large-scale or small-scale forms of violence [82,84,85]. This result is confirmed in our analysis: *ethnic fractionalization* is statistically insignificant in three out of seven models, and when it is significant, it is associated with *less* unrest. This finding is often seen as a puzzle since the case study literature shows that most civil wars are fought along ethnic or religious lines. Our results suggest that it is not ethnic fractionalization *per se* that matters but whether ethnicity is politically salient. Horizontal inequality could be one of the factors that increase the salience of ethnicity. In the light of this literature, our results on the number of ethnic groups is also interesting. They suggest that it is the total number of groups, not ethnic fractionalization, that is associated with political instability.

Social norms and institutions are a ubiquitous component of our social life and decision-making [66,138,139]. While there is a growing number of theoretical studies in economics and cultural evolution that account for psychological or sociological factors [96,98,140,141], these efforts have not led so far to falsifiable predictions in studies of social conflict that distinguish between material and non-material forces [41]. Our model offers such predictions. Moreover, historians have argued that some societies become more successful and/or stable than others due to their social norms and institutions [142]. Our theoretical and empirical results support these conclusions.

Our model was intended to describe states that rely on large-scale cooperation between its segments operating under largely stable economic and political rules. Adapting the model to other types of societies, e.g. those relying on a forced transfer of resources and goods up a social hierarchy, is an interesting direction for future work. Horizontal inequality was a factor in some prehistoric economic organization and chiefdoms [143]. In contrast to our model, cycles of breakdown in complexity of early societies [144–149] are typically driven by deaths of the rulers, exogenous events, or certain demographic processes [74,150] that we did not consider here. Some data suggest that conflict among feudal elites—landlords, clerics, kings, and officeholders—gave rise to capitalism itself [150]. Our modelling framework might be useful for describing these processes.

More generally, data show that while inequality within human civilizations has generally increased from the Stone Age to today [5], significant reductions in inequality have repeatedly occurred, each typically preceded by violent events [4,5,151]. As high inequality becomes unsustainable, it becomes reduced again by wars, social strife and/or revolutions [4].

We did not model the (violent) conflict between the factions explicitly but only a necessary condition for it—the breakdown of cooperation between factions. Nevertheless, in our model the factions switching to opposition reduced the maximum amount of benefits potentially available to the ruling elites punishing them as a result. More generally, the presence of counter-elites can not only decrease the overall benefit but also increase the costs of production.

Our models can be generalized in a number of ways. For example, one can add a normative 'bonus' to a faction's effective effort y_i for being in the opposition [62] or impose a material penalty on defecting factions as a result of some kind of 'punishment' administered by the state. One can allow for political concessions from the state [47,48,91], effects of foresight [152,153], and/or social learning [154] in decision-making. One can make utility of conformity dependent on 'affinity' between factions which in turn can depend on the history of past decisions. We modelled bounded rationality of our agents in a simple way using myopic best response subject to errors. Recent approaches using forward-looking agents or the 'theory of mind' (reviewed in [153]) suggest added complexity to incorporate into future revisions of our model. We used an S-shaped production function aimed to capture the law of diminishing returns in economics in a simple form. From game theoretic work, we know that the shape of production function can affect the resulting dynamics and equilibria. We treated parameters η_0 and η_1 as constant. Support for the state and the level of conformity could be a function of inequality within society, however. In our model, we have treated each faction as a single unit which makes or not a fixed contribution to the production of collective goods. In reality, factions are composed of individuals and can have certain structure. Factions can decide how much effort/resources to invest into competing for power, and it may not be optimal to invest all resources, especially when the chance to increase the share of the collective good in the next stage is slim. The presence of vertical inequality within factions can have a significant effect to their propensity to remain loyal to the state or to rebel [27,28,155]. The effects of these additional important forces and factors remain to be explored. The methods of experimental economics have proved to be useful in uncovering patterns and processes of human decision-making both at the individual level [156,157] and at the group level [158,159]. Our model is relatively simple and thus might be amenable to experimental implementation. It would be interesting to test its predictions in an experimental set-up. Overall, sharpening the focus of theoretical work will be hardly possible without additional empirical data to validate and parametrize the models.

There are also limitations to this study in articulating a model simulation with real-world statistics aggregated at the scale of nations, which do not match simulation results in a one-to-one fashion. To address this, future studies could test the model results more directly, either at the scale of experimental psychology under controlled conditions, or potentially using detailed historical data. This could correct for the approximate connections we make between rule of law as an empirical proxy for incumbency, for example. Future models will also address questions of endogeneity and reverse causality.

Our findings have important implications in light of the economic consequences of the COVID-19 pandemic. Research shows that the coronavirus has increased inequality, particularly inequality between ethnic groups worldwide. Low income households have experienced larger income reduction and the effect has been more pronounced among certain ethnic groups, often those that were already disadvantaged before the pandemic [160–162]. Moreover, according to the World Bank, more than 80 million people attained extreme poverty in 2020 because of the pandemic [163]. At the same time, according to various news reports, many of the world's richest people have become richer both because of the pandemic and because of the policies adopted by governments to respond to it [164–166]. Within the USA, the proportion of African–Americans among a county population predicted higher death and infection rates [167], which is likely due to socio-economic inequality (high population households, underlying health conditions, tendency to work service jobs). These disparities in pandemic effect have fuelled tensions between groups. This suggests that mitigating the effect of COVID-19 on horizontal inequality may be crucial if we are to limit its destabilizing effects.

Data accessibility. Data and replication codes are available at https://houlec.com/research/ and https://datadryad.org/stash/share/ME4jCUQ01MjZgxcY5Pp00qF30nbg90N8tmFn1YBcLdc.

Authors' contributions. C.H.: conceptualization, data curation, investigation, methodology, validation, visualization, writing—original draft, writing—review and editing; D.J.R.: conceptualization, data curation, investigation, methodology, resources, writing—original draft, writing—review and editing; R.A.B.: conceptualization, investigation, resources, writing—original draft, writing—review and editing; S.G.: conceptualization, formal analysis, funding acquisition, resources, writing—original draft, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Competing interests. We declare we have no competing interests.

Funding. S.G. was supported by the US Army Research Office grant nos. W911NF-14-1-0637 and W911NF-17-1-0150, the Office of Naval Research grant no. W911NF-18-1-0138, the Air Force Office of Scientific Research grant no. FA9550-21-1-0217, the National Institute for Mathematical and Biological Synthesis through NSF award no. EF-0830858, and by the University of Tennessee, Knoxville. D.J.R. and R.A.B. received funding from the College of Arts and Sciences and the Office of Research and Engagement at the University of Tennessee.

Acknowledgements. We thank D. J. Lawson, S. Minhas, M. J. O'Brien, B. Prins and D. Tverskoi for comments and access to data, and L. Bromham, M. Cardillo, X. Hua and S. Greenhill for sharing data.

References

1. Marx K. 1867 *Das kapital*. Hamburg, Germany: Verlag von Otto Meisner.
2. Hobson JA. 1902 *Imperialism: a study*. New York, NY: James Pott & Co.
3. Flannery KV, Marcus J. 2012 *The creation of inequality: how our prehistoric ancestors set the stage for monarchy, slavery, and empire*. Cambridge, MA: Harvard University Press.
4. Milanovic B. 2016 *Global inequality: a new approach for the age of globalization*. Cambridge, MA: Belknap Press.
5. Schneidel W. 2018 *The great leveler: violence and the history of inequality from the stone age to the twenty-first century*. Princeton, NJ: Princeton University Press.
6. Piketty T. 2013 *Capital in the twenty-first century*. Cambridge, MA: Harvard University Press.
7. Alesina A, Perotti R. 1996 Income distribution, political instability, and investment. *Eur. Econ. Rev.* **40**, 1203–1228. (doi:10.1016/0014-2921(95)00030-5)
8. Jayadev A, Bowles S. 2006 Guard labor. *J. Dev. Econ.* **79**, 328–348. (doi:10.1016/j.jdeveco.2006.01.009)
9. Alesina A, Michalopoulos S, Papaioannou E. 2016 Ethnic inequality. *J. Polit. Econ.* **124**, 428–488. (doi:10.1086/685300)
10. Baldwin K, Huber JD. 2010 Economic versus cultural differences: forms of ethnic diversity and public goods provision. *Am. Polit. Sci. Rev.* **104**, 644–662. (doi:10.1017/S0003055410000419)
11. Kyriacou AP. 2013 Ethnic group inequalities and governance: evidence from developing countries. *Kyklos* **66**, 78–101. (doi:10.1111/kykl.12012)
12. Becker GS. 1968 Crime and punishment: an economic approach. *J. Polit. Econ.* **76**, 169–217. (doi:10.1086/259394)
13. Daly M. 2017 *Killing the competition: economic inequality and homicide*. New York, NY: Routledge.
14. Fajnzylber P, Lederman D, Loayza N. 2002 Inequality and violent crime. *J. Law Econ.* **45**, 1–40. (doi:10.1086/338347)
15. Hicks DL, Hicks JH. 2014 Jealous of the joneses: conspicuous consumption, inequality, and crime. *Oxf. Econ. Pap.* **66**, 1090–1120. (doi:10.1093/oep/gpu019)
16. Lichbach MI. 1989 An evaluation of 'does economic inequality breed political conflict?' studies. *World Polit.* **41**, 431–470. (doi:10.2307/2010526)
17. Engerman S, Sokoloff K, Urquiola M, Acemoglu D. 2002 Factor endowments, inequality, and paths of development among new world economies. *Economía* **3**, 41–109. (doi:10.1353/eco.2002.0013)
18. Stewart F. 2005 Horizontal inequalities: a neglected dimension of development. In *Wider perspectives on global development*, pp. 101–135. London, UK: Palgrave Macmillan.
19. Houle C. 2009 Inequality and democracy: why inequality harms consolidation but does not affect democratization. *World Polit.* **61**, 589–622. (doi:10.1017/S0043887109990074)
20. Houle C. 2016 Why class inequality breeds coups but not civil wars. *J. Peace Res.* **53**, 680–695. (doi:10.1177/0022343316652187)
21. Roe MJ, Siegel JI. 2011 Political instability: effects on financial development, roots in the severity of

economic inequality. *J. Comp. Econ.* **39**, 279–309. (doi:10.1016/j.jce.2011.02.001)

22. Bartusevičius H. 2014 The inequality–conflict nexus re-examined: income, education and popular rebellions. *J. Peace Res.* **51**, 35–50. (doi:10.1177/0022343313503179)
23. Cramer C. 2005 Inequality and conflict: a review of an age-old concern. Technical report, United Nations Research Institute for Social Development.
24. Stewart F. 2008 *Horizontal inequalities and conflict: understanding group violence in multiethnic societies*. Basingstoke, UK: Palgrave Macmillan.
25. Cederman L-E, Skrede Gleditsch K, Buhaug H. 2013 *Inequality, grievances, and civil war*. Cambridge, UK: Cambridge University Press.
26. Hillesund S *et al.* 2018 Horizontal inequality and armed conflict: a comprehensive literature review. *Can. J. Dev. Stud.* **39**, 463–480. (doi:10.1080/02255189.2018.1517641)
27. Houle C, Park C, Kenny PD. 2019 The structure of ethnic inequality and ethnic voting. *J. Polit.* **81**, 187–200. (doi:10.1086/700200)
28. Houle C. 2019 Religion, language, race and ethnic voting. *Elect. Stud.* **61**, 1020–1052. (doi:10.1016/j.electstud.2019.102052)
29. Cederman L-E, Wimmer A, Min B. 2010 Why do ethnic groups rebel? New data and analysis. *World Polit.* **62**, 87–119. (doi:10.1017/S0043887109990219)
30. Canelas C, Gisselquist RM. 2018 Horizontal inequality as an outcome. *Oxf. Dev. Stud.* **46**, 305–324. (doi:10.1080/13600818.2018.1508565)
31. Stewart F, Brown G, Mancini L. 2010 Monitoring and measuring horizontal inequalities. Technical report, Centre for Research on Inequality, Human Security and Ethnicity, Oxford.
32. Brown GK, Langer A. 2016 A general class of social distance measures. *Polit. Anal.* **24**, 211–225. (doi:10.1093/pan/mpw002)
33. Canelas C, Gisselquist RM. 2019 Horizontal inequality and data challenges (vol. 143, p. 157, 2019). *Soc. Indic. Res.* **145**, 969–984. (doi:10.1007/s11205-019-02157-1)
34. Alvaredo F, Chancel L, Piketty T, Saez E, Zucman G. 2018 World inequality database.
35. Stevens JR, Cushman FA, Hauser MD. 2005 Evolving the psychological mechanisms for cooperation. *Annu. Rev. Ecol. Syst.* **36**, 499–518. (doi:10.1146/ecolsys.2005.36.issue-1)
36. Østby G. 2008 Polarization, horizontal inequalities and violent civil conflict. *J. Peace Res.* **45**, 143–162. (doi:10.1177/0022343307087169)
37. Østby G. 2013 Inequality and political violence: a review of the literature. *Int. Area Stud. Rev.* **16**, 206–231. (doi:10.1177/2233865913490937)
38. Cederman L-E, Weidmann NB, Gleditsch KS. 2011 Horizontal inequalities and ethnonationalist civil war: a global comparison. *Am. Polit. Sci. Rev.* **105**, 478–495. (doi:10.1017/S000305 5411000207)
39. Cederman L-E, Gleditsch KS, Buhaug H. 2013 *Grievances and inequality in civil wars*. New York, NY: Cambridge University Press.
40. Huber JD, Suryanarayan P. 2016 Ethnic inequality and the ethnification of political parties evidence from India. *World Polit.* **68**, 149–188. (doi:10.1017/S0043887115000349)
41. Blattman C, Miguel E. 2010 Civil war. *J. Econ. Lit.* **48**, 3–57. (doi:10.1257/jel.48.1.3)
42. Longres H. 2000 *Human behavior in the social environment*. 3rd edn. Belmont, CA: Wadsworth/Thompson Learning.
43. Easterly W, Ritzen J, Woolcock M. 2006 Social cohesion, institutions and growth. *Econ. Polit.* **18**, 103–120. (doi:10.1111/ecpo.2006.18.issue-2)
44. Solt F. 2008 Economic inequality and democratic political engagement. *Am. J. Polit. Sci.* **52**, 48–60. (doi:10.1111/j.1540-5907.2007.00298.x)
45. Lindert PH. 1994 The rise of social spending, 1880–1930. *Explor. Econ. Hist.* **31**, 1–37. (doi:10.1006/exeh.1994.1001)
46. Gradstein M, Milanovic B. 2004 Does liberte = egalite? A survey of the empirical links between democracy and inequality with some evidence on the transition economies. *J. Econ. Surv.* **18**, 515–537. (doi:10.1111/j.0950-0804.2004.00229.x)
47. Acemoglu D, Naidu S, Restrepo P, Robinson JA. 2015 Democracy, redistribution, and inequality. In *Handbook of income distribution*, vol. 2B (eds F Bourguignon, T Atkinson), pp. 1885–1966. Amsterdam, The Netherlands: Elsevier.
48. Acemoglu D, Robinson JA. 2006 *Economic origins of dictatorship and democracy*. Cambridge, UK: Cambridge University Press.
49. Acemoglu D, Robinson JA. 2008 Persistence of power, elites, and institutions. *Am. Econ. Rev.* **98**, 267–293. (doi:10.1257/aer.98.1.267)
50. Besley T, Persson T. 2009 The origins of state capacity: property rights, taxation, and politics. *Am. Econ. Rev.* **99**, 1218–1244. (doi:10.1257/aer.99.4.1218)
51. Persson T, Tabellini G. 2009 Democratic capital: the nexus of political and economic change. *Am. Econ. J. Macroecon.* **1**, 88–126. (doi:10.1257/mac.1.2.88)
52. Acemoglu D, Egorov G, Sonin K. 2012 Dynamics and stability of constitutions, coalitions, and clubs. *Am. Econ. Rev.* **102**, 1446–1447. (doi:10.1257/aer.102.4.1446)
53. Svolik MW. 2013 Contracting on violence: the moral hazard in authoritarian repression and military intervention in politics. *J. Conflict Resolut.* **57**, 765–794. (doi:10.1177/0022002712449327)
54. Gorodnichenko Y, Roland G. 2015 Culture, institutions and democratization. NBER Working Paper, No. 21117.
55. Roland G, Xie Y. 2016 Culture and collective action. In *Contemporary issues in development economics* (ed. T Besley), pp. 44–60. London, UK: Palgrave Macmillan.
56. Bisin A, Verdier T. 2017 On the joint evolution of culture and institutions. National Bureau of Economic Research, Working Paper 23375. See https://www.nber.org/papers/w23375.
57. Esteban J, Ray D. 2011 Linking conflict to inequality and polarization. *Am. Econ. Rev.* **101**, 1345–1374. (doi:10.1257/aer.101.4.1345)
58. Tullock G. 1980 Efficient rent seeking. In *Toward a theory of the rent-seeking society* (eds JM Buchanan, RD Tollison, G Tullock), pp. 97–112. College Station, TX: Texas A & M University.
59. Konrad KA. 2009 *Strategy and dynamics in contests*. Oxford, UK: Oxford University Press.
60. Montalvo JG, Reynal-Querol M. 2005 Ethnic polarization, potential conflict, and civil wars. *Am. Econ. Rev.* **95**, 796–816. (doi:10.1257/00028280 54201468)
61. Gehlbach S, Sonin K, Svolik MW. 2016 Formal models of nondemocratic politics. *Annu. Rev. Polit. Sci.* **19**, 565–584. (doi:10.1146/polisci.2016.19.issue-1)
62. Lawson DJ, Oak N. 2014 Apparent strength conceals instability in a model for the collapse of historical states. *PLoS ONE* **9**, e96523. (doi:10.1371/journal.pone.0096523)
63. Olson M. 1965 *Logic of collective action: public goods and the theory of groups*. Cambridge, MA: Harvard University Press.
64. Scott JF. 1971 *Internalization of norms*. Englewood Cliffs, NJ: Prentice-Hall.
65. Richerson PJ, Boyd R. 2005 *Not by genes alone. How culture transformed human evolution*. Chicago, IL: University of Chicago Press.
66. Bicchieri C. 2006 *The grammar of society. The nature and dynamics of social norms*. Cambridge, UK: Cambridge University Press.
67. Nunn N. 2012 Culture and the historical process. *Econ. Theory Dev. Regions* **27**, S108–S126. (doi:10.1080/20780389.2012.664864)
68. Alesina A, Giuliano P. 2015 Culture and institutions. *J. Econ. Lit.* **53**, 898–944. (doi:10.1257/jel.53.4.898)
69. Ruck DJ, Bentley RA, Lawson DJ. 2020 Cultural prerequisites of socioeconomic development. *R. Soc. Open Sci.* **7**, 190725. (doi:10.1098/rsos.190725)
70. Turchin P, Gavrilets S, Goldstone JA. 2018 Linking 'micro' to 'macro' models of state breakdown to improve methods for political forecasting. *Cliodyn.: J. Quant. Hist. Cult. Evol.* **2**, 159–181. (doi:10.21237/C7CLIO8237429)
71. Goldstone JA. 1991 *Revolution and rebellion in the early modern world*. Berkeley, CA: University of California Press.
72. Goldstone JA. 2014 *Revolutions: a very short introduction*. Oxford, UK: Oxford University Press.
73. Goldstone JA. 2016 How valuable are the indicators? *The Cipher Brief*. See https://www.thecipherbrief.com/how-valuable-are-the-indicators.
74. Turchin P. 2003 *Historical dynamics: why states rise and fall*. Princeton, NJ: Princeton University Press.
75. Granovetter M. 1978 Threshold models of collective behavior. *Am. J. Soc.* **83**, 1420–1443. (doi:10.1086/226707)
76. Kuran T. 1989 Sparks and prairie fires: a theory of unanticipated political revolution. *Public Choice* **61**, 41–74. (doi:10.1007/BF00116762)
77. Macy MW. 1991 Chains of cooperation: threshold effects in collective action. *Am. Soc. Rev.* **56**, 730–747. (doi:10.2307/2096252)

78. Centola D, Willer R, Macy M. 2005 The emperor's dilemma: a computational model of self-enforcing norms. *Am. J. Soc.* **110**, 1009–1040. (doi:10.1086/427321)
79. Meirowitz A, Tucker JA. 2013 People power or a one-shot deal? A dynamic model of protest. *Am. J. Polit. Sci.* **57**, 478–490. (doi:10.1111/ajps.2013.57.issue-2)
80. Brummitt CD, Barnett G, D'Souza RM. 2015 Coupled catastrophes: sudden shifts cascade and hop among interdependent systems. *J. R. Soc. Interface* **12**, 20150712. (doi:10.1098/rsif.2015.0712)
81. Gubler JR, Selway JS. 2012 Horizontal inequality, crosscutting cleavages, and civil war. *J. Conflict Resolut.* **56**, 206–232. (doi:10.1177/0022002711431416)
82. Houle C, Bodea C. 2017 Ethnic inequality and coups in sub-Saharan Africa. *J. Peace Res.* **54**, 382–396. (doi:10.1177/0022343316685140)
83. Houle C. 2015 Ethnic inequality and the dismantling of democracy: a global analysis. *World Polit.* **67**, 469–505. (doi:10.1017/S0043887115000106)
84. Fearon JD, Laitin DD. 2003 Ethnicity, insurgency, and civil war. *Am. Polit. Sci. Rev.* **97**, 75–98. (doi:10.1017/S0003055403000534)
85. Collier P, Hoeffler A. 2004 Greed and grievance in civil wars. *Oxf. Econ. Pap.* **56**, 563–595. (doi:10.1093/oep/gpf064)
86. Hurwicz L. 1996 Institutions as families of game forms. *Jpn. Econ. Rev.* **47**, 113–132. (doi:10.1111/jere.1996.47.issue-2)
87. Turchin P. 2016 *Ages of discord. A structural-demographic analysis of American history*. Chaplin, CT: Beresta Books.
88. Gavrilets S. 2015 Collective action problem in heterogeneous groups. *Phil. Trans. R. Soc. B* **370**, 20150016. (doi:10.1098/rstb.2015.0016)
89. Sandler T, Tschirhart J. 1997 Club theory: thirty years later. *Public Choice* **93**, 335–355. (doi:10.1023/A:1017952723093)
90. Gavrilets S, Fortunato L. 2014 A solution to the collective action problem in between-group conflict with within-group inequality. *Nat. Commun.* **5**, 3526. (doi:10.1038/ncomms4526)
91. North DC, Wallis JJ, Weingast BR. 2009 *Violence and social orders: a conceptual framework for interpreting recorded human history*. Cambridge, UK: Cambridge University Press.
92. Hofbauer J, Sigmund K. 1998 *Evolutionary games and population dynamics*. Cambridge, UK: Cambridge University Press.
93. Sandholm WH. 2010 *Population games and evolutionary dynamics*. Cambridge, MA: MIT Press.
94. Azar OH. 2004 What sustains social norms and how they evolve? the case of tipping. *J. Theor. Biol.* **54**, 49–64. (doi:10.1016/j.jebo.2003.06.001)
95. Azar OH. 2008 Evolution of social norms with heterogeneous preferences: a general model and an application to the academic review process. *J. Theor. Biol.* **65**, 420–435. (doi:10.1016/j.jebo.2006.03.006)
96. Gavrilets S, Richerson PJ. 2017 Collective action and the evolution of social norm internalization. *Proc. Natl Acad. Sci. USA* **114**, 6068–6073. (doi:10.1073/pnas.1703857114)
97. Gavrilets S. 2020 The dynamics of injunctive social norm. *Evol. Hum. Sci.* **2**, e60. (doi:10.1017/ehs.2020.58)
98. Gavrilets S. 2021 Coevolution of actions, personal norms, and beliefs about others in social dilemmas. *Evol. Hum. Sci.* **3**, E44. (doi:10.1017/ehs.2021.40)
99. Fudenberg D, Tirole J. 1992 *Game theory*. Cambridge, MA: The MIT Press.
100. Tembine H. 2017 Mean-field-type games. *AIMS Math.* **2**, 706–735. (doi:10.3934/Math.2017.4.706)
101. Piotrowski EW, Sladkowski J. 2003 An invitation to quantum game theory. *Int. J. Theor. Phys.* **42**, 1089–1099. (doi:10.1023/A:1025443111388)
102. Rashevsky N. 1949 Mathematical biology of social behavior. III. *Bull. Math. Biol.* **11**, 255–271. (doi:10.1007/BF02477979)
103. DeGroot MH. 1974 Reaching a consensus. *J. Am. Stat. Assoc.* **69**, 118–121. (doi:10.1080/01621459.1974.10480137)
104. Watts DP, Mitani JC. 2002 Hunting behavior of chimpanzees at Ngogo, Kibale National Park, Uganda. *Int. J. Primatol.* **23**, 1–28. (doi:10.1023/A:1013270606320)
105. Friedkin NE, Proskurnikov AV, Tempo R, Parsegov SE. 2016 Network science on belief system dynamics under logic constraints. *Science* **354**, 321–326. (doi:10.1126/science.aag2624)
106. Zino L, Ye M, Cao M. 2020 A two-layer model for coevolving opinion dynamics and collective decision-making in complex social systems. *Chaos* **20**, 083107. (doi:10.1063/5.0004787)
107. Kashima Y, Perfors A, Ferdinand V, Pattenden E. 2021 Ideology, communication and polarization. *Phil. Trans. R. Soc. B* **376**, 20200133. (doi:10.1098/rstb.2020.0133)
108. Rabin M. 1994 Cognitive dissonance and social change. *J. Econ. Behav. Organ.* **24**, 177–194. (doi:10.1016/0167-2681(94)90066-3)
109. Kuran T, Sandholm WH. 2008 Cultural integration and its discontents. *Rev. Econ. Stud.* **75**, 201–228. (doi:10.1111/roes.2008.75.issue-1)
110. Calabuig V, Olcina G, Panebianco F. 2018 Culture and team production. *J. Econ. Behav. Organ.* **149**, 32–45. (doi:10.1016/j.jebo.2018.03.004)
111. Jowett GS, O'Donnell V. 1992 *Propaganda and persuasion*, 2nd edn. Newbury Park, CA: Sage Publications.
112. Alesina A, Fuchs-Schündeln N. 2007 Good-bye Lenin (or not?): the effect of communism on people's preferences. *Am. Econ. Rev.* **97**, 1507–1528. (doi:10.1257/aer.97.4.1507)
113. Rozenas A, Stukal D. 2019 How autocrats manipulate economic news: evidence from Russia's state-controlled television. *J. Polit.* **81**, 982–996. (doi:10.1086/703208)
114. Bowles S, Gintis H. 1976 *Schooling in capitalist America: educational reform and the contradictions of economic life*. London, UK: Routledge.
115. Cantoni D, Chen Y, Yang DY, Yuchtman N, Zhang YJ. 2021 Curriculum and ideology. *J. Polit. Econ.* **125**, 338–392. (doi:10.1086/690951)
116. Gigerenzer G, Selten R. 2001 *Bounded rationality: the adaptive toolbox*. Cambridge, MA: MIT Press.
117. Goeree JK, Holt CA, Palfrey TR. 2016 *Quantal response equilibrium*. Princeton, NJ: Princeton University Press.
118. Gavrilets S. 2015 Collective action and the collaborative brain. *J. R. Soc. Interface* **12**, 20141067. (doi:10.1098/rsif.2014.1067)
119. Humphreys M, Sachs J, Stiglitz JE. 2007 *Escaping the resource curse*. New York, NY: Columbia University Press.
120. Banks AS, Wilson KA. 2013 Cross-national time-series data archive. See https://www.cntsdata.com.
121. Wimmer A, Cederman L-E, Min B. 2009 Ethnic politics and armed conflict: a configurational analysis of a new global data set. *Am. Soc. Rev.* **74**, 316–337. (doi:10.1177/000312240907400208)
122. Kaufmann D, Kraay A, Mastruzzi M. 2011 The worldwide governance indicators: methodology and analytical issues. *Hague J. Rule Law* **3**, 220–246. (doi:10.1017/S1876404511200046)
123. Fukuyama F. 2009 *The origins of political order: from prehuman times to the French revolution*. New York, NY: Farrar, Straus and Giroux.
124. Inglehart R, Welzel C. 2005 *Modernization, cultural change, and democracy: the human development sequence*. Cambridge, UK: Cambridge University Press.
125. World Bank. 2018 World development indicators. See https://databank.worldbank.org/source/world-development-indicators.
126. Hegre H, Sambanis N. 2006 Sensitivity analysis of empirical results on civil war onset. *J. Conflict Resolut.* **50**, 508–535. (doi:10.1177/0022002706289303)
127. Eff A, Dow M. 2009 How to deal with missing data and Galton's problem in cross-cultural survey research: a primer for R. *Struct. Dyn.* **3**. (doi:10.5070/SD933003305)
128. Turchin P. 2018 Fitting dynamic regression models to Seshat data. *Cliodynamics* **9**, 25–58. (doi:10.21237/C7clio9137696)
129. Bromham L, Xia H, Cardillo M, Schneemann H, Greenhill S. 2018 Parasites and politics: why cross-cultural studies must control for relatedness, proximity and covariation. *R. Soc. Open Sci.* **5**, 181100. (doi:10.1098/rsos.181100)
130. Buhaug H, Gleditsch KS. 2008 Contagion or confusion? Why conflicts cluster in space. *Int. Stud. Q.* **52**, 215–233. (doi:10.1111/j.1468-2478.2008.00499.x)
131. Correlates of War Project. Direct contiguity data, 1816–2016, version 3.2.
132. Wooldridge J. 2010 *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press.
133. Easterly W. 2007 Inequality does cause underdevelopment: insights from a new instrument. *J. Dev. Econ.* **84**, 589–622. (doi:10.1016/j.jdeveco.2006.11.002)

134. Deininger K, Squire L. 1996 A new data set measuring income inequality. *World Bank Econ. Rev.* **10**, 565–591. (doi:10.1093/wber/10.3.565)
135. Salazar C. 2015 Long-run effects of democracy on income inequality: evidence from repeated cross-sections. World Bank Policy Research Working Paper.
136. Roodman D. 2009 How to do xtabond2: an introduction to difference and system GMM in Stata. *Stata J.* **9**, 86–136. (doi:10.1177/1536867X0900900106)
137. Nickell S. 1981 Biases in dynamic models with fixed effects. *Econometrica* **49**, 1417–1426. (doi:10.2307/1911408)
138. Ensminger J, Henrich J. 2014 *Theoretical foundations: the coevolution of social norms, intrinsic motivation, markets, and the institutions of complex societies*. New York, NY: Russel Sage Foundation.
139. Fehr E, Schurtenberger I. 2018 Normative foundations of human cooperation. *Nat. Hum. Behav.* **2**, 458–468. (doi:10.1038/s41562-018-0385-5)
140. Bowles S. 2016 *The moral economy: why good incentives are no substitute for good citizens*. New Haven, CT: Yale University Press.
141. Loewenstein G, Molnar A. 2018 The renaissance of belief-based utility in economics. *Nat. Hum. Behav.* **2**, 166–167. (doi:10.1038/s41562-018-0301-z)
142. Morris I. 2015 *Foragers, farmers, and fossil fuels. How human values evolve*. Princeton, NJ: Princeton University Press.
143. White JC. 1995 Incorporating heterarchy into theory on socio-political development: the case from Southeast Asia. In *Heterarchy and the analysis of complex societies* (eds RM Ehrenreich, CL Crumley, JE Levy), pp. 101–123. Archeological Papers of the American Anthropological Association, no. 6, Arlington, VA.
144. Wright HT. 1977 Recent research on the origin of the state. *Annu. Rev. Anthropol.* **6**, 379–397. (doi:10.1146/annurev.an.06.100177.002115)
145. Wright HT. 1984 Prestate political formations. In *On the evolution of complex societies. Essays in honor of Harry Hoijer* (eds W Sander, HT Wright, RM Amams), pp. 41–77. Malibu, CA: Undina Press.
146. Marcus J. 1992 Political fluctuations in Mesoamerica. *Natl Geogr. Res. Explor.* **8**, 392–411.
147. Marcus J. 1998 The peaks and valleys of ancient states an extension of the dynamic model. In *Archaic states* (eds G Feinman, J Marcus), pp. 59–94. Santa Fe, NM: SAR Press.
148. Anderson DG. 1994 *The Savannah river chiefdoms: political change in the late prehistoric southeast*. Tuscaloosa, AL: University of Alabama Press.
149. Gavrilets S, Anderson DG, Turchin P. 2010 Cycling in the complexity of early societies. *Cliodyn.: J. Theor. Math. Hist.* **1**, 5536t55r. (doi:10.21237/C7CLIO11193)
150. Lachmann R. 2000 *Capitalists in spite of themselves: elite conflict and economic transitions in early modern Europe*. New York, NY: Oxford University Press.
151. Levitt MS. 2019 The neglected role of inequality in explanations of the collapse of ancient states. *Cliodyn.: J. Quant. Hist. Cult. Evol.* **10**, 31–53. (doi:10.21237/C7CLIO10142572)
152. Perry L, Duwal Shrestha M, Vose MD, Gavrilets S. 2018 Collective action problem in heterogeneous groups with punishment and foresight. *J. Stat. Phys.* **172**, 293–312. (doi:10.1007/s10955-018-2012-2)
153. Gavrilets S. 2020 Foresight, punishment, and cooperation. In *Advances in culture and psychology* (eds MJ Gelfand, C-Y Chiu, Y-Y Hong). New York, NY: Oxford University Press.
154. Roithmayr D, Isakov A, Rand D. 2015 Should law keep pace with society? Relative update rates determine the co-evolution of institutional punishment and citizen contributions to public goods. *Games* **6**, 124–149. (doi:10.3390/g6020124)
155. Houle C, Miller MK. 2019 Social mobility and democratic attitudes: evidence from Latin America and sub-Saharan Africa. *Comp. Polit. Stud.* **52**, 1610–1647. (doi:10.1177/0010414019830719)
156. Smith VL. 2008 Experimental methods in economics. In *The new Palgrave dictionary of economics*, 2nd edn (eds S Durlauf, LE Blume), pp. 4262–4275. London, UK: Palgrave Macmillan.
157. Jacquemet N, L'Haridon O. 2018 *Experimental economics: method and applications*. Cambridge, UK: Cambridge University Press.
158. Dechenaux E, Kovenock D, Sheremeta RM. 2015 A survey of experimental research on contests, all-pay auctions and tournaments. *Exp. Econ.* **18**, 609–669. (doi:10.1007/s10683-014-9421-0)
159. Sheremeta RM. 2014 Behavioral dimensions of contests. In *Companion to the political economy of rent seeking* (eds R Congleton, A Hillman), pp. 150–164. Northampton, MA: Edward Elgar Publishing.
160. Hacioglu S, Känzig DR, Surico P. 2021 The distributional impact of the pandemic. *Eur. Econ. Rev.* **134**, 103680. (doi:10.1016/j.euroecorev.2021.103680)
161. Holst H, Fessler A, Niehoff S. 2020 Covid-19, social class and work experience in Germany: inequalities in work-related health and economic risks. *Eur. Soc.* **23**, 1–18. (doi:10.4171/JEMS)
162. Bodea C, Houle C, Kim H. 2021 Do financial crises increase income inequality? *World Dev.* **147**, 105635. (doi:10.1016/j.worlddev.2021.105635)
163. Aguilar R, Lakner C, Mahler D, Wu H. 2020 Updated estimates of the impact of COVID-19 on global poverty. *World Bank Blog*. See https://blogs.worldbank.org/opendata/updated-estimates-impact-covid-19-global-poverty-looking-back-2020-and-outlook-2021.
164. Cooper C. 2020 The next pandemic: rising inequality. *Politico*. See https://www.politico.com/news/2020/04/28/the-next-pandemic-rising-inequality-219753.
165. Collins C. 2020 Billionaires are getting even richer from the pandemic. Enough is enough. *CNN Business*. See https://www.cnn.com/2020/04/28/perspectives/inequality-coronavirus-billionaires/index.html.
166. Vesoulis A. 2020 Coronavirus may disproportionately hurt the poor—and that's bad for everyone. *Time*. See https://time.com/5800930/how-coronavirus-will-hurt-the-poor/.
167. Ruck DJ, Bentley RA, Borycz J. 2021 Early warning of vulnerable counties in a pandemic using socio-economic variables. *Econ. Hum. Biol.* **41**, 100988. (doi:10.1016/j.ehb.2021.100988)

Electronic supplementary material for "Inequality between identity groups and social unrest," Journal of Royal Society Interface, by Christian Houle, Damian Ruck, Alexander Bentler and Sergey Gavrilets.

Below:

- Part 1 provides electronic supplementary modeling (pp.3-8),
- Part 2 explains data analysis and shows robustness test (pp.8-21),
- Part 3 shows additional simulation results (p.22).

Table S1 lists model variables, functions, parameters and statistics.

Table S1: Model variables, functions, parameters and statistics.

	Symbols	Their meaning
Variables	x_i	faction effort ($x_i = 0$ or $x_i = 1$)
	f_i	faction power ($0 \leq f_i \leq 1, \sum f_i = 1$)
Functions	X	number of cooperating factions, $X = \sum x_i$
	$P(X)$	normalized production function, $P = \frac{X^\kappa}{X^\kappa + X_0^\kappa}$
	R_i	faction's payoff, $R_i = R_i^0 + [v_i(B + nbP(X)) - c]x_i$
	v_i	faction's share of the collective good, $v_i = \frac{f_i x_i}{\sum f_j x_j}$
	y_i	faction's effort in the political game, $y_i = R_i(1 - \varepsilon + \varepsilon f_i)$
	u_i	utility function for the state faction: $u_s(x_s) = R_s(x_s) + \eta_0 x_s$
		for a non-sate faction: $u_i = R_i + [\eta_0 + \eta_1(2\tilde{x} - 1]x_i$
	$\tilde{x}$	average effort among the non-"state" factions, $\tilde{x} = \frac{X-1-x_i}{n-1}$
Parameters	n, R_i^0	number of factions and their endowments
	B, b, c	benefit and cost parameters
	X_0, κ	half-effort and steepness parameters of the production function
	ε	incumbent strength parameter
	η_0	normative value of conforming with the "state"
	η_1	normative value of conforming with peers
	λ	precision parameter in the QRE approach
	ν	udpate probability
	γ, ϱ	initial inequality in power and inequality in endowment
	σ	standard deviation of the stochastic perturbation of power
	δ	cost of changing action
Statistics from model	T	time to the collapse of cooperation
	G	Gini index computed using factions' payoffs R_i
Statistics from data	GDP	GDP; proxy for R
	E	horizontal inequality; proxy of G
	I	social unrest; proxy of T
	D	rule of law; proxy of ε
	S	support for the state; proxy of η_0
	C	conformity; proxy of η_1

Part 1. electronic supplementary Modeling

1.1 Additional details on numerical simulations

Stochasticity. In our model, faction i chooses to cooperate (i.e. $x_i = 1$) with probability

$$p_i = \frac{1}{1 + \exp[\lambda(u_i(0) - u_i(1))]}. \tag{S1}$$

Otherwise it defects. (This is a model with logit errors (1).) Here $u_i(0)$ and $u_i(1)$ are the corresponding utilities (defined by equations 4 of the main text), and λ is a (non-negative) precision parameter which captures the errors and stochasticity in the economic game.

We also allow for stochasticity in the political game by perturbing the effective effort: $y_i \to y_i + \psi$, where ψ is a number drawn randomly and independently from a truncated normal distribution with zero mean and small variance σ^2.

Initial conditions. For generating the initial distribution of power and the distribution of endowments we use a "broken stick" distribution (2). Specifically, we randomly divide the interval $[0, 1]$ into n intervals by generating $n - 1$ independent random values from a uniform distribution on $[0, 1]$. Let κ_i be the length of the ith interval produced by this process.

Initial power of the ith faction is set to $f_i(0) = (1 - \gamma)\,\frac{1}{n} + \gamma\kappa_i$, where $0 \leq \gamma \leq 1$ is a parameter measuring the initial inequality in power. If $\gamma = 0$, each faction has the same power $1/n$ initially. If $\gamma = 1$, the initial power distribution is the "broken stick" distribution.

The endowment of faction i is set as $R_i^0 = c + \varrho\kappa_i$, where κ_i is a random number from the "broken stick" distribution (generated independently from that used for initial power) and $\varrho \geq 0$ is a parameter measuring the amount of resource distributed unequally. That is, each faction gets an equal endowment c plus a share κ_i of the extra amount ϱ.

Statistics. The time T to the first collapse of cooperation was measured as the time until X becomes ≤ 1 for the first time. If this never happens T is set to the length of simulations (i.e., $T = 4000$). The duration of the transient period τ in the dynamics of the Gini index G is defined as the first time moment τ such that the average of Gini index $G(t)$ for t between τ and T is equal the $G(\tau)$: $G(\tau) = \frac{1}{T-\tau}\,\sum_{t=\tau}^{T} G(t)$. That is, for $t > \tau$, Gini index can be seen as randomly fluctuating around the mean value $G(\tau)$. Figure 1 in the main text marks τ and T with green and red stars, respectively.

1.2 Additional information on numerical results

Simpson index. The turnover of dominant factions was measured by the Simpson diversity index in Figure 3c of the main text. Let y_i the the proportion of time that faction i was most dominant, $\sum y_i = 1$. The Simpson index is defined as

$$S = \frac{1}{\sum y_i^2}. \tag{S2}$$

For example, if only one faction, say the first, was in power, $y_1 = 1, y_i = 0$ for all $i > 1$, then $S = 1$. If each faction was most dominant an equal amount of time, then $y_i = 1/n$, and $S = n$. To exclude periods of instability when the identities of the most dominant factions change rapidly, we considered only the time when the power of the most dominant faction $f_{\max} > 1.05/n$.

Periodicity. To find the period of fluctuations illustrated in Figure 3d of the main text, we used the data on the power of the most dominant faction. Specifically, we first computed the

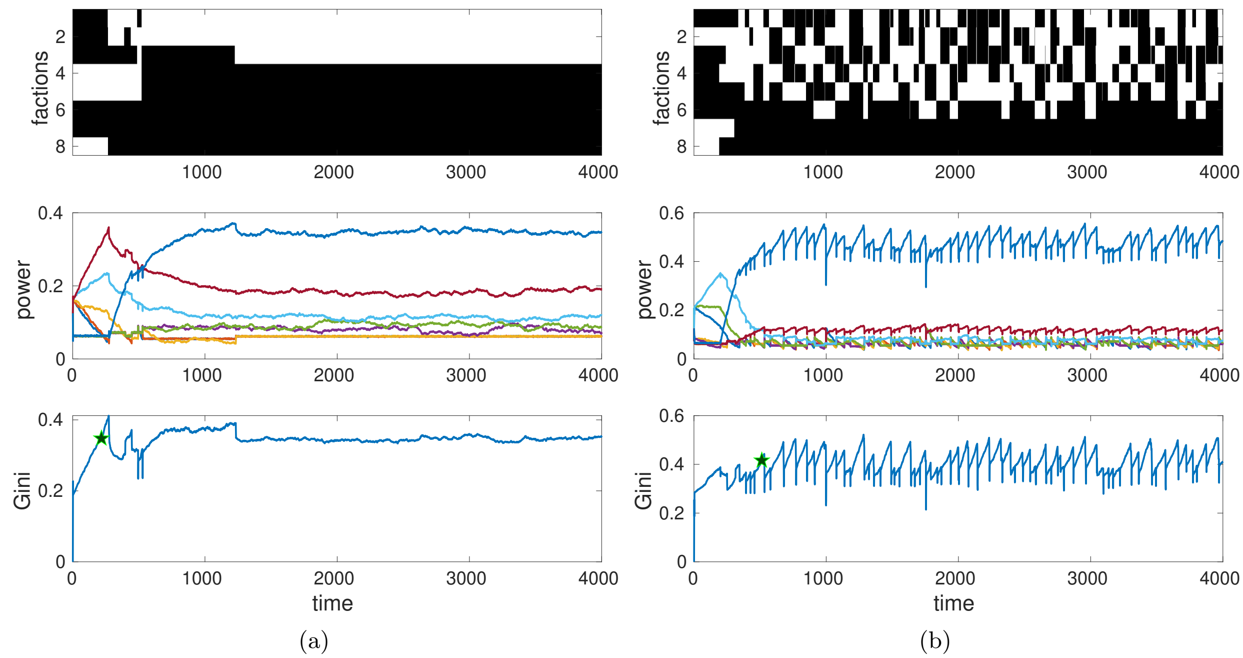

Figure S1: Examples of the dynamics observed with inequality in endowments. Two runs with $G = 8, b = 32, x_0 = 0.5, \varepsilon = 0.01, \gamma = 0, \eta_0 = 0, \eta_1 = 0, \delta = 0.25, \kappa = 2, \nu = 0.5, \lambda = \infty$ and $\rho = 0.1$. Factions are sorted by their endowment from the smallest (on top) to the highest (at the bottom).

corresponding autocorrelation function using Matlab command *autocorr* and then found its first peak using Matlab command *findpeaks* with MinPeakHeight=0.05 and MinPeakDistance=15.

Figure S1 shows examples of possible dynamics with differences in the endowment of factions.

1.3 Analytical results

To get a better intuition about for the model, it is illuminating to consider several special cases assuming infinite precision.

Zero production equilibrium. At a system state with zero production (i.e. with all $x_i = 0$), nobody is motivated to switch to cooperation if $B + nbP(1) < c + \delta$, that is, of the total cost of the effort and switching the state is larger than the total benefit. The latter inequality can be rewritten as

$$\frac{nb}{c + \delta - B} < 1 + X_0^{\kappa}. \tag{S3}$$

Note that this condition is never satisfied if $B > c + \delta$, that is, if the society's natural resource B is large enough.

Threshold effect. Each elite benefits from cooperation only if its power is larger than a critical value. Otherwise it is in its direct material interests to move to the counter elite. Specifically, a cooperating faction i is motivated to switch to defection if $v_i(B + bnP(X)) - c < -\delta$, which is the same as

$$f_i < \frac{c - \delta}{B + bnP(X)} \sum_{j \in C} f_j, \tag{S4}$$

where the sum is taken over the set C of all currently cooperating factions including the focal faction i. See (3) for a review on collective action problem in heterogeneous groups.

Dynamics of power with fixed production. To see the trends in the dynamics of power, let us assume, for a moment, that factions keep cooperating regardless of their power is (i.e., that all x_i are set to 1). We consider three cases separately.

No incumbency effect: $\varepsilon = 0$. If the incumbency effect is absent (i.e., if $\varepsilon = 0$), then the distribution of power converges to a unique equilibrium at which the power f_i^* of each faction is proportional to its endowment.

So see this, first notice that with $\varepsilon = 0$, $y_i = R_i$. To simplify notation, let $Q = bnP(n)$ be the total production assuming that all n factions cooperate. Then

$$\begin{aligned} R_i =& R_i^0 - c + f_i Q, \\ \sum R_i =& \sum (R_i^0 - c) + \sum f_j Q = (R^0 - c)X + Q, \\ f_i' =& \frac{R_i}{\sum R_j} = \frac{R_i^0 - c + f_i Q}{(R^0 - c)X + Q}, \end{aligned}$$

where $R^0 = \sum R_i^0/n$ is the average baseline resource. Thus, the dynamics of powers f_i are described by a system of linear difference equations. Its equilibrium solution is

$$f_i^* = \frac{1}{n}\,\frac{R_i^0 - c}{R^0 - c}, \tag{S5}$$

which is feasible if $R^0 > c$. If $R^0 = c$ (which requires that $R_j^0 = c$ for all j), the power distribution does not change from its initial values.

Maximum incumbency effect: $\varepsilon = 1$. In this case the system quickly evolves to an equilibrium state where one faction has all power. There can be up to n such equilibria. Which particular faction becomes dominant depends on initial powers and endowments.

To see this, first notice that with $\varepsilon = 1$, so that $y_i = R_i f_i$. Then the distribution of power changes according to the system of difference equations

$$f_i' = \frac{R_i f_i}{\sum_j R_j f_j}. \tag{S6}$$

The latter equation is a discrete time version of the selection (replicator) equation with power f_i being analogous to the gene frequency and resource R_i to its fitness. In biological terminology, selection is linear positive frequency-dependent. In this case, all power quickly concentrates on one of the factions. Which faction it is depends on initial conditions and the base-line resource levels. From equations (S6), it is straightforward to show that the state, where faction k has all the power, is locally stable if for all $i \neq k$,

$$R_i^0 < R_k^0 + Q.$$

If all factions have equal endowments, the system will quickly move to a state where the dominant faction is the one with the highest initial power.

For example,, let $R_i^0 = c$ for all i. In this case, $\frac{f_i'}{f_j'} = \frac{R_i f_i}{R_j f_j}$ and $\frac{R_i}{R_j} = \frac{v_i}{v_j} = \frac{f_i}{f_j}$. Thus, $\frac{f_i'}{f_j'} = \left(\frac{f_i}{f_j}\right)^2$. We conclude that all power (and resource) will quickly concentrate on just one faction which has the highest power initially.

Let $R_i^0 \neq c$ for all i but there are just two cooperating factions. Then, writing $f_1 = f, f_2 = 1-f$,

$$\begin{aligned} R_1 =& R_1^0 - c + fB, \ R_2 = R_2^0 - c + (1-f)B, \\ f' =& \frac{R_1 f}{R_1 f + R_2(1-f)}, \\ f' - f =& f(1-f)\frac{R_1 - R_2}{R_1 f + R_2(1-f)} = f(1-f)\frac{R_1^0 - R_2^0 + (2f-1)B}{R_1 f + R_2(1-f)}. \end{aligned}$$

At equilibrium, $f = 0, f = 1$, or $f = f^* \equiv \frac{1}{2} + \frac{R_2^0 - R_1^0}{B}$. If the last equilibrium is feasible (i.e. $0 \leq f^* \leq 1$), it is unstable and f evolves to 0 on 1 depending on initial conditions. Otherwise the system evolves to a state where the faction with the largest endowment becomes dominant.

Intermediate incumbency ε. With arbitrary ε, $y_i = R_i(1-\varepsilon+\varepsilon f_i)$. We can get some analytical progress for a number of special cases of the model.

First, assume that $R_i^0 = c$ for all i. If all n factions cooperate, then $R_i = f_i Q$ and

$$f_i' = \frac{f_i(1-\varepsilon+\varepsilon f_i)}{S},$$

where $S = \sum_j f_j(1-\varepsilon+\varepsilon f_j) = 1-\varepsilon+\varepsilon \sum f_j^2$. The above system of equations is identical to those describing a model of symmetric, linear positive frequency-dependent selection with fitness $1-\varepsilon+\varepsilon f_i$ and parameter ε measuring the strength of selection (and the corresponding time-scale). Note also that $\sum f_j^2 = n\overline{f^2} = n(\overline{f}^2 + \mathrm{var}(f)) = \frac{1}{n} + n\,\mathrm{var}(f)$. Then

$$\Delta f_i = f_i' - f_i = \varepsilon \frac{f_i(f_i - \sum f_j^2)}{S}$$

If $\varepsilon \ll 1$, then $S \approx 1$, and we can use a differential approximation $\Delta f_i \approx \frac{df_i}{dt} = \varepsilon f_i(f_i - \sum f_j^2) = \varepsilon f_i(w_i - \overline{w})$, where $w_i = f_i, \overline{w} = \sum w_i f_i$. That is, we end up with the standard replicator equation (4).

Also, for any contributing factions i and j,

$$\frac{f_i'}{f_j'} = \frac{f_i}{f_j}\,\frac{1-\varepsilon+\varepsilon f_i}{1-\varepsilon+\varepsilon f_j},$$

so that if $\varepsilon > 0$ and $\frac{f_i}{f_j} < 1$, then $\frac{f_i'}{f_j'} < \frac{f_i}{f_j}$. This shows once again that the most powerful faction will keep increasing its power at the expense of all other factions.

Let faction 1 have power f and each of the other $n-1$ factions have smaller power $\frac{1-f}{n-1}$. Then $\sum f_j^2 = f^2 + (n-1)\left(\frac{1-f}{n-1}\right)^2$. Assuming that ε is small and using the differential approximation as above,

$$\frac{df}{dt} = \varepsilon f\left(f - f^2 - \frac{(1-f)^2}{n-1}\right) = \varepsilon f^2(1-f)\left(1 - \frac{1}{n-1}\,\frac{1-f}{f}\right).$$

This can be solved explicitly for $t = t(f)$ which can be looked at graphically.

Assume that there are only two factions. First, let their endowments are equal: $R_1^0 = R_2^0 = c$.

Then

$$\begin{aligned}
R_1 =& fB, \\
R_2 =& (1-f)B, \\
f' =& \frac{f(1-\varepsilon+\varepsilon f)}{f[1-\varepsilon+\varepsilon f]+(1-f)[1-\varepsilon+\varepsilon(1-f)]}, \\
f'-f =& \frac{\varepsilon f(1-f)(2f-1)}{1-2\varepsilon f(1-f)}.
\end{aligned}$$

The last equation is analogous to the model of underdominant selection. The equilibria are $f = 0, f = 1/2$ and $f = 1$. The middle one is unstable while equilibria $f = 0$ and $f = 1$ are locally stable.

Second, let $R_1^0 = R_2^0 = R^0 > c$. Define $\Delta = R^0 - c \geq 0$. Then

$$f'-f = \frac{(2f-1)[f(1-f)\varepsilon B - \Delta(1-\varepsilon)]}{B[1-2\varepsilon f(1-f)]+\Delta(2-\varepsilon)}.$$

Thus, at equilibrium $f = 1/2$ or $f(1-f) = \Delta(1-\varepsilon)/(\varepsilon B)$. The right-hand side of the last equation must be smaller than 1/4 for the existence of two more equilibria which is the case if

$$\varepsilon > \frac{4\Delta}{4\Delta+B}, \text{ or, equivalently, if } \frac{\Delta}{B} < \frac{1}{4}\,\frac{\varepsilon}{1-\varepsilon}.$$

In this case, the equilibrium $f = 1/2$ is locally unstable and the system evolves to one of the other two equilibria depending on initial conditions. With smaller ε, the system equilibrates at $f = 1/2$ for all initial conditions.

Third, let $R_1^0 - c = \delta > 0, R_2^0 - c = 0$. Then f changes according to equation

$$f'-f = \frac{(1-f)[f(2f-1)\varepsilon B + \delta(1-\varepsilon+\varepsilon f)]}{B[1-2\varepsilon f(1-f)]+\delta(1-\varepsilon+\varepsilon f)}.$$

Thus, there is one equalibrium at $f = 1$ and we have a quadratic equation for the two other equilibria: $2B\varepsilon x^2 - \varepsilon(B-\delta)x + \delta(1-\varepsilon) = 0$. The latter has two roots between 0 and 1 if $\delta < B$ (the difference in endowments is smaller than what can be obtain from the collective good) and $\varepsilon > \frac{8B\delta}{B^2+6B\delta+\delta^2}$ (the incumbent effect is strong, so that initial difference in power can be protected even with less endowment). It cannot have just one root between 0 and 1. The existence of two roots implies the dependence on initial conditions. Otherwise, the first faction (which has the largest endowment) will always dominate.

Finally, consider a general case: $R_1^0 - c = \Delta + \delta/2, R_2^0 - c = \Delta - \delta/2$ with $\Delta \geq 0, 0 \leq \delta/2 \leq \Delta$. Then f changes according to equation

$$f'-f = \frac{f(1-f)(2f-1)\varepsilon B + \frac{\delta}{2}[1-\varepsilon+2\varepsilon f(1-f)] - \Delta(1-\varepsilon)(2f-1)}{B[1-2\varepsilon f(1-f)]+\frac{\delta}{2}\varepsilon(2f-1)+\Delta(2-\varepsilon)}.$$

Let us denote the numerator of the above expression as $G(f)$.

One can show that $G(0) = (1-\varepsilon)(\Delta+\delta) > 0, G(1) = -(1-\varepsilon)(\Delta-\delta) < 0$, so that there is always one equilibrium. If it is the only equilibrium, it must be stable (because function $G(f)$ will be decreasing at it).

For $G(f)$ to have 3 positive real roots, it is *necessary* that $\delta < 3B/2, \delta < BP/2 + \frac{\Delta(1-\varepsilon)}{\delta}$ (Descartes' rule of signs, p.40 in Spravochnik). This is always the case for small enough δ.

Note that $G(1), G'(1), G''(1), G'''(1) < 0$. Then, using Budan-Fourier theorem, the *number of roots between 0 and 1* is equal to the number of sign changes (or that minus two) in the sequence:

$$\begin{aligned} G(0) =&(1-\varepsilon)(2\Delta+\delta) > 0, \\ G'(0) =&-\varepsilon B - 2\Delta(1-\varepsilon) + \varepsilon\delta, \\ G''(0) =&4\varepsilon(3B-\delta), \\ G'''(0) =&-24\varepsilon B < 0. \end{aligned}$$

If $G'(0)$ and $G''(0)$ have the same sign, there is only one change in signs, so there is only one root between 0 and 1. Same happens if $G'(0)$ is positive but $G''(0)$ is negative. A *necessary* condition to have 3 roots is, thus, that $-\varepsilon B - 2\Delta(1-\varepsilon) + \varepsilon\delta < 0$ but $3B - \delta > 0$. These conditions can be rewritten as $\delta < \min(Q + 2\Delta\frac{1-\varepsilon}{\varepsilon}, 3Q)$. So, there can be one or three equilibria for f. In the latter case, the outcome depends on initial conditions.

Summarizing, with an intermediate incumbent effect (i.e., if $0 < \varepsilon < 1$), analyses of models with just two factions show that depending on the difference in endowments, the system can have a single globally stable equilibrium or two locally stable equilibria. In the former case, the faction with a higher endowment will always have a higher power at equilibrium. In the latter case, the final state of the system depends on the initial distribution of powers. This outcome is promoted if the difference in endowments (i.e. $|R_1^0 - R_2^0|$) is small relative to what can be obtained from production (i.e. $bnP(X)$) and the incumbent effect ε is strong, so that initial differences in power can be decisive in defining the dynamics. In this case, the faction with a smaller endowment can still dominate if it is able to "take advantage" of the initial power imbalance. The time-scale of the model dynamics is mostly controlled by parameter ε.

Expectation for the general dynamics. On the basis of these results we can expect specific dynamics in the general case. Let precision be infinite (i.e., $\lambda = \infty$). Assume that all factions cooperate initially and that the incumbent effect is absent (i.e. $\varepsilon = 0$). Then the system will equilibrate at a particular state (see above). Assume that the incumbent effect is present (i.e. $\varepsilon > 0$). Then if factions have equal endowments, as within-group power inequality grows, they will one by one move to the opposition until only one or zero factions make efforts. In the former case, the system will state in this state indefinitely. In the latter case, power equality among factions will be immediately restored and they once again start contributing to production. This will be the start of a new cycle of growing inequality eventually leading to the collapse of cooperation. If factions have different endowments, the system may either cycle or equilibrate at a particular state. In evolutionary biology models, even small advantages in fitness can lead to the establishment of advantageous types in the population. Because resource levels here are analogous to fitness in the replicator equation, we expect that even relatively small differences in endowments will have significant effects on the dynamics of power. If we add stochasticity to the model (i.e., if $\lambda < \infty$), the system can jump between different attractors.

Part 2. Data Analysis

2.1 Data

Social unrest

The dependent variables capture different forms of social unrest: riots, strikes, assassinations, anti-government demonstrations, guerrillas and revolutions (5). Riots are defined as "Any violent demonstration or clash of more than 100 citizens involving the use of physical force" (User-Manual, p.11); anti-government demonstrations as "Any peaceful public gathering of at least 100 people for the primary purpose of displaying or voicing their opposition to government policies or authority, excluding demonstrations of a distinctly anti-foreign nature" (Ibid.); general strikes as "Any strike of 1,000 or more industrial or service workers that involves more than one employer and that is aimed at national government policies or authority" (Ibid.); revolutions as "Any illegal or forced change in the top government elite, any attempt at such a change, or any successful or unsuccessful armed rebellion whose aim is independence from the central government" (Ibid.); guerilla warfare as "Any armed activity, sabotage, or bombings carried on by independent bands of citizens or irregular forces and aimed at the overthrow of the present regime" (Ibid.); and assassinations as "Any politically motivated murder or attempted murder of a high government official or politician" (Ibid.). Our main dependent variable (*Unrest Index*) gives how many forms of instability a given country has experienced. We also run regressions on six dummy variables that capture whether a country has experienced at least one riot, assassination, strike, guerrilla, revolution and anti-government demonstration within a given year.

Horizontal inequality

We measure horizontal inequality using 'ethnic inequality' data from (6), which calculates a Gini index to equals 0 when all ethnic groups have equal wealth and 1 when they are maximally unequal. It uses night time luminosity as proxy for the economic development of small sub-national areas, then calculates ethnic inequality by comparing the average luminosity of regions inhabited by different ethnic groups. Though alternative measures of horizontal inequality exists (7–9), we use Alesina's 'ethnic inequality' measure because it offers measurements for 98 nations from the WEVS and correlates with standard measures of vertical inequality (6).

The ethnic composition of geographical areas is taken from two data sets, Geo-Referencing of Ethnic Groups (GREG) and Ethnologue, each having different strengths. Ethnologue do not account for the major migrations during the last 500 years, which means GREG has is more detailed for the Americas and Australasia. However, Ethnologue is more fine-grained generally, offering more detail in Africa and Asia. To see how these differences effect our analysis, we use both Ethnologue (Table 2) and the GREG (Table S6) measures of horizontal inequality.

There are a number of data issues with measuring horizontal inequality (10). Therefore, we repeated our analysis using an alternative measure of horizontal inequality that estimates the income of different ethnic groups within each country using self-reported survey responses (9). This measure is different to Alesina's data is three main respects: it uses raw survey data at the individual level; is limited to only democratic countries and uses an alternative formulation of inequality (not the Gini index).

Rule of law

We measure 'Rule of Law' using the World Bank's Worldwide Governance Indicators (11). From survey data, it encapsulates perceptions that the rules and laws of a nation are being followed, with a focus on the police, the courts, contract enforcement and property rights. Using an Unobserved Components Model to parsimoniously combine data from over thirty data sources, the 'Rule of Law' indicator is z-scored with most values falling between -2.5 and 2.5.

Conformity and support for institutions

World and European Values Survey data. We measured normative cultural values using the World and European Values Survey (WEVS) (12, 13) which combined consist of the same 64 questions, over a 25 year period, administered to 476,583 participants from 109 unique nations. The surveys were administered in 5 waves at 5 year intervals, beginning in 1990. Not all nations were available for each wave of the survey, nonetheless 84/109 were still asked the same 64 (ordinal scale) questions more than once. Missingness was limited (1.6%), so mean imputation was sufficient, prior to data processing.

Principal Component Analysis. We the selected WEVS items that encapsulate the concepts of conformity and support for institutions. Support for institutions is defined using questions asking if respondents have confidence in their nations parliament, civil service, government, police, political parties, press and armed forces. Similarly, we defined conformity using questions asking what parents considered valuable traits for their children: obedience and religion (conformity) and independence and determination (anti-conformity). The WEVS item for conformity were chosen to match the well established autonomy index (14) which is the reverse of conformity.

This gave us an eleven dimension matrix, which we compressed using principal component analysis. We found that two components explain 45% of the total variation and each were interpretable as conformity and support for institutions using the component loadings, i.e. the correlated WEVS items (table S3). Therefore, we used PC1 to measure 'support for institutions' and PC2 to measure 'conformity'.

Table S2: Principal Component Analysis: component loading matrix

	PC1: support for inst.	PC2: conformity
Confidence: Parliament	0.83	0.03
Confidence: Civil Service	0.74	-0.01
Confidence: Government	0.80	-0.02
Confidence: Police	0.66	-0.04
Confidence: Political Parties	0.76	0.07
Confidence: Press	0.57	-0.02
Confidence: Armed Forces	0.55	-0.18
Child Qualities: Obedience	-0.01	0.66
Child Qualities: Religion	-0.06	0.64
Child Qualities: Independence	-0.02	-0.60
Child Qualities: Determination	0.01	-0.47

Number of Groups

Number of Groups gives the country's number of politically relevant ethnic groups. It is taken from the Ethnic Power Relations dataset (15).

Former British and French Colony

Former British Colony and *Former French Colony* are dummy variables that take the value one if a country is a former British/French colonies. They are taken from Bodea et al. (16).

Polity Score and Polity Score Squared

The Polity score is a measure of democracy that ranges from -10 to 10, where -10 indicate full autocracy and 10 full democracy.

Ethnic Fractionalization

Our measure of *Ethnic Fractionalization* is taken from the Ethnic Power Relations dataset (15). It gives the probability that two randomly selected citizens of the country are members of different ethnic groups.

GDP per capita and Growth

We use GDP per capita in constant 2010 U.S. dollars from World Bank data (17). It is logged. We calculate the (one-year) growth rate using GDP per capita.

Table S3 gives basic descriptive statistics for each variable included in the analysis.

Table S3: Descriptive Statistics

	Mean	Median	Std. Dev.	Min.	Max.
Social Unrest Index	1.115	1	1.303	0	6
Riots	.241	0	.428	0	1
Assassinations	.124	0	.331	0	1
Strikes	.107	0	.309	0	1
Guerrillas	.141	0	.348	0	1
Revolutions	.128	0	.335	0	1
Demonstrations	.371	0	.483	0	1
Horizontal Inequality	.512	.537	.281	0	.979
Rule of Law	.061	-.154	.969	-1.852	2.100
Conformity	.094	.051	.455	-1.051	1.114
Respect for Institutions	.007	-.063	.466	-1.023	1.806
Number of Groups	5.247	4	6.576	1	47
Former British Colony	.271	0	.444	0	1
Former French Colony	.067	0	.251	0	1
Polity Score	4.572	7	6.195	-10	10
Ethnic Fractionalization	.391	.356	.260	.004	.899
GDP pc (logged)	9.216	9.279	1.001	6.549	11.274
Growth	3.005	3.078	6.151	-61.236	105.439

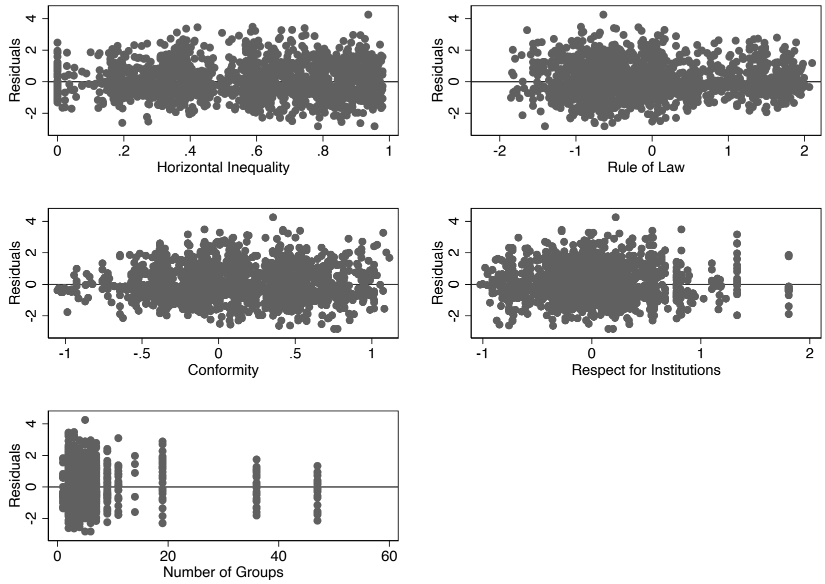

Figure S2: Residuals associated with Model 1 of Table 2.

2.2 Regression results

This section presents a number of robustness tests. First, in Table 2, we only include countries in which ethnicity is politically relevant. In Table S4, we show that the results are unchanged when we widen the sample to countries in which ethnicity is not politically salient. Second, in Models 2-7 of Table 2, we employ dummy variables as our dependent variables. For example, the *Riot* variable takes the value one if a country has experienced at least one riot within a given year. In Table S5, we redo the analysis with count variables that give, for example, the number of riots a country has experienced within that year. These models are ran using Ordinary Least Squares (using the command *reg* in *STATA*). Results are unchanged.

Third, in the main analysis, we use the horizontal inequality data of Alesina et al. (6) based on the ethnic classifications from Ethnologue. In Table S6, we redo the analysis with their horizontal inequality measure based on the ethnic classifications from the Geo-Referencing of Ethnic Groups (GREG). In Table S7, we repeat our analysis using an alternative measure of country-level horizontal inequality, constructed by Houle based on self-reported income and ethnic identity from survey data (9). One disadvantage of this dataset for our purpose is that it only covers democracies (since it was developed to study democratic breakdowns). On balance, results are somewhat weaker, but the effect of horizontal inequality on the main dependent variable (*Unrest Index*) remains statistically significant at the 5% level.

Fourth, to make sure that the results are not driven by outliers on horizontal inequality, Tables S9 and S8 exclude observations with horizontal inequality values above the 95th percentile and below the 5th percentile, respectively. Results are stable.

Fifth, in all models, we cluster standard errors by country to address issues of temporal autocorrelation, i.e. observations for the same country at different points in time are not independent of each other (18). Here, we adopt two additional strategies to address temporal autocorrelation. First, in Table S10 we redo Table 2 using Prais–Winsten estimations, which accounts for serial correlation of type AR(1). Unlike Models 2-7 of Table 2, these are linear models. At the bottom of

Table S4: Determinants of Social Unrest – Includes Countries in which Ethnicity is not Politically Relevant

	Dependent Variables						
	Index	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged DV	.502	.967	1.001	.993	1.779	1.799	.758
	(.029)***	(.087)***	(.096)***	(.121)***	(.123)***	(.140)***	(.078)***
Spatial DV	.201	.914	.580	.971	.477	-.159	.763
	(.036)***	(.137)***	(.225)***	(.234)***	(.289)*	(.212)	(.138)***
Horizontal Inequality	.389	.510	.269	.249	.352	.496	.484
	(.128)***	(.177)***	(.212)	(.228)	(.278)	(.226)**	(.174)***
Rule of Law	-.203	-.237	-.324	-.099	-.208	-.162	-.200
	(.055)***	(.088)***	(.082)***	(.097)	(.092)**	(.085)*	(.070)***
Conformity	.189	.026	.229	.189	.392	.301	.235
	(.098)*	(.134)	(.142)	(.186)	(.168)**	(.171)*	(.123)*
Respect for Institutions	.007	.042	-.190	.006	.214	.120	-.083
	(.081)	(.127)	(.129)	(.178)	(.151)	(.132)	(.105)
Number of Groups	.017	.013	.018	.009	.021	.007	.034
	(.005)***	(.009)	(.009)**	(.007)	(.006)***	(.008)	(.005)***
Former British Colony	.062	.228	.228	.256	-.069	-.265	.133
	(.116)	(.144)	(.147)	(.174)	(.191)	(.192)	(.144)
Former French Colony	.016	.011	.067	.118	.197	-.150	-.106
	(.074)	(.091)	(.182)	(.159)	(.162)	(.160)	(.109)
Polity Score	.020	.016	.033	.049	.022	.005	.017
	(.006)***	(.010)	(.010)***	(.012)***	(.011)*	(.010)	(.009)**
Polity Score sq.	-.002	-.003	-.002	-.0009	-.004	-.002	-.004
	(.001)	(.002)*	(.002)	(.003)	(.002)*	(.002)	(.002)**
Ethnic Fractionalization	-.071	-.004	-.304	-.503	.111	-.074	-.167
	(.141)	(.218)	(.232)	(.299)*	(.270)	(.244)	(.186)
GDP pc (logged)	.208	.262	.073	.030	.253	-.088	.335
	(.042)***	(.065)***	(.068)	(.083)	(.071)***	(.074)	(.055)***
Growth	-.004	-.003	-.008	-.012	-.001	.003	-.011
	(.003)	(.003)	(.005)*	(.006)*	(.006)	(.006)	(.004)***
N	2228	2228	2228	2228	2228	2228	2228
Log-Lik.	-3146.59	-999.45	-646.952	-657.487	-563.796	-498.739	-1201.702

Note: Redoes table 2 with all countries, including those in which ethnicity is not politically relevant. All models are ran with *STATA*. Model 1 is ran using Ordinary Least Squares (with the command *reg*) and models 2-7 using Probit estimations (with the command *probit*). All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S5: Determinants of Social Unrest – Continuous Dependent Variables

	Dependent Variables					
	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged DV	.316 (.043)***	.461 (.103)***	.628 (.097)***	.192 (.058)***	1.196 (.198)***	.172 (.041)***
Spatial DV	.225 (.040)***	.152 (.123)	.747 (.219)***	.127 (.036)***	-.068 (.196)	.075 (.045)*
Horizontal Inequality	1.097 (.390)***	.485 (.472)	.605 (.553)	.777 (.780)	.934 (.412)**	.993 (.321)***
Rule of Law	-.158 (.179)	-.531 (.206)***	.092 (.229)	-.841 (.271)***	-.245 (.170)	-.267 (.148)*
Conformity	.310 (.293)	.758 (.277)***	.409 (.391)	1.064 (.483)**	.838 (.350)**	.359 (.198)*
Respect for Institutions	-.0005 (.231)	-.328 (.273)	-.288 (.348)	.477 (.328)	.317 (.230)	-.320 (.201)
Number of Groups	.027 (.014)*	.035 (.016)**	.020 (.014)	.038 (.019)**	.016 (.014)	.042 (.014)***
Former British Colony	.376 (.262)	.418 (.295)	.599 (.345)*	-.160 (.410)	-.657 (.368)*	.345 (.224)
Former French Colony	-.055 (.234)	.090 (.434)	.275 (.302)	.190 (.473)	-.374 (.291)	-.108 (.181)
Polity Score	.018 (.019)	.066 (.020)***	.073 (.025)***	.094 (.025)***	.007 (.018)	.011 (.017)
Polity Score sq.	-.003 (.004)	-.004 (.004)	-.001 (.006)	-.016 (.007)**	-.004 (.004)	-.002 (.003)
Ethnic Fractionalization	-.280 (.377)	-1.151 (.509)**	-.928 (.601)	.397 (.648)	-.117 (.395)	-.349 (.335)
GDP pc (logged)	.335 (.128)***	-.042 (.147)	-.082 (.191)	.693 (.207)***	-.142 (.123)	.519 (.124)***
Growth	-.004 (.008)	-.024 (.008)***	-.006 (.028)	.0004 (.013)	-.011 (.009)	-.021 (.008)***
N	1889	1889	1889	1889	1889	1889
Log-Lik.	-1717.202	-912.89	-799.334	-1155.253	-686.379	-2548.226

Note: Redoes table 2 with slightly different dependent variables. They give the number of riots, assassinations, etc., that a country has experienced within a given year. All models are ran with *STATA* and Ordinary Least Squares (with the command *reg*). All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S6: Determinants of Social Unrest – Uses the GREG measure of Horizontal Inequality of Alesina et al. (6).

	Dependent Variables						
	Index	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged DV	.500	.971	1.010	.951	1.746	1.811	.755
	(.031)***	(.092)***	(.101)***	(.137)***	(.125)***	(.148)***	(.079)***
Spatial DV	.207	.975	.581	1.137	.402	-.223	.817
	(.039)***	(.150)***	(.245)**	(.258)***	(.302)	(.220)	(.151)***
Horizontal Inequality	.408	.578	.241	.294	.558	.708	.353
	(.197)**	(.277)**	(.313)	(.366)	(.412)	(.347)**	(.291)
Rule of Law	-.180	-.210	-.298	-.033	-.197	-.138	-.174
	(.065)***	(.100)**	(.095)***	(.119)	(.100)**	(.092)	(.082)**
Conformity	.246	.067	.273	.282	.446	.381	.288
	(.112)**	(.143)	(.150)*	(.204)	(.184)**	(.185)**	(.141)**
Respect for Institutions	-.004	-.002	-.142	-.008	.229	.191	-.094
	(.099)	(.150)	(.133)	(.215)	(.169)	(.136)	(.120)
Number of Groups	.020	.016	.019	.013	.020	.006	.036
	(.005)***	(.009)*	(.009)**	(.007)*	(.006)***	(.008)	(.004)***
Former British Colony	.087	.277	.225	.328	-.077	-.272	.145
	(.125)	(.153)*	(.149)	(.177)*	(.194)	(.199)	(.161)
Former French Colony	.047	.056	.074	.100	.229	-.012	-.105
	(.102)	(.096)	(.229)	(.171)	(.183)	(.172)	(.124)
Polity Score	.017	.012	.036	.044	.021	.005	.013
	(.007)**	(.011)	(.011)***	(.013)***	(.012)*	(.011)	(.009)
Polity Score sq.	-.002	-.002	-.002	-.0003	-.004	-.002	-.003
	(.002)	(.002)	(.002)	(.003)	(.002)	(.003)	(.002)
Ethnic Fractionalization	-.021	.051	-.280	-.446	.087	-.001	-.116
	(.157)	(.232)	(.232)	(.317)	(.269)	(.225)	(.203)
GDP pc (logged)	.202	.250	.062	.004	.267	-.059	.333
	(.047)***	(.075)***	(.079)	(.090)	(.073)***	(.070)	(.062)***
Growth	-.004	-.002	-.011	-.008	-.00006	-.010	-.011
	(.003)	(.005)	(.006)*	(.008)	(.008)	(.005)*	(.005)**
N	1889	1889	1889	1889	1889	1889	1889
Log-Lik.	-2704.828	-864.008	-581.181	-548.559	-518.19	-453.106	-1042.124

Note: Redoes table 2 with the GREG measure of horizontal inequality of Alesina et al. (6). All models are ran with *STATA*. Model 1 is ran using Ordinary Least Squares (with the command *reg*) and models 2-7 using Probit estimations (with the command *probit*). All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S7: Determinants of Social Unrest – Uses the Measure of Horizontal Inequality of Houle (9).

	Dependent Variables						
	Index	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged DV	.470	.965	.897	.949	1.734	1.478	.693
	(.045)***	(.132)***	(.138)***	(.163)***	(.201)***	(.230)***	(.096)***
Spatial DV	.238	.995	1.100	.922	-.007	-.405	1.060
	(.058)***	(.184)***	(.327)***	(.321)***	(.421)	(.282)	(.183)***
Horizontal Inequality	.112	.076	-.088	.141	.205	.212	.003
	(.048)**	(.073)	(.053)*	(.075)*	(.065)***	(.056)***	(.081)
Rule of Law	-.331	-.550	-.279	-.242	-.402	-.192	-.299
	(.117)***	(.174)***	(.160)*	(.134)*	(.159)**	(.158)	(.115)***
Conformity	.427	.221	.507	.488	.865	.660	.706
	(.132)***	(.188)	(.175)***	(.201)**	(.285)***	(.235)***	(.170)***
Respect for Institutions	.432	.535	-.154	.361	.988	.911	.245
	(.134)***	(.213)**	(.201)	(.280)	(.275)***	(.191)***	(.135)*
Number of Groups	.059	.063	.042	.042	.076	.072	.077
	(.013)***	(.022)***	(.017)**	(.017)**	(.021)***	(.017)***	(.015)***
Former British Colony	-.066	.209	.263	.256	-.366	-1.182	-.043
	(.148)	(.208)	(.217)	(.206)	(.262)	(.207)***	(.196)
Former French Colony	.088	.661			.279	-1.008	.121
	(.251)	(.332)**			(.393)	(.329)***	(.240)
Polity Score	-.006	-.043	.075	-.008	.056	.003	-.035
	(.011)	(.017)**	(.025)***	(.014)	(.015)***	(.013)	(.016)**
Polity Score sq.	-.0001	.003	-.003	.007	-.009	-.004	.001
	(.002)	(.003)	(.004)	(.005)	(.004)**	(.003)	(.003)
Ethnic Fractionalization	-.241	-.325	-.490	-.844	-.066	-.206	-.466
	(.180)	(.258)	(.311)	(.383)**	(.444)	(.378)	(.240)*
GDP pc (logged)	.364	.592	.0003	.093	.636	-.130	.466
	(.109)***	(.151)***	(.169)	(.138)	(.163)***	(.159)	(.121)***
Growth	-.001	.001	-.018	-.014	-.007	-.011	.002
	(.005)	(.010)	(.006)***	(.010)	(.009)	(.008)	(.008)
N	1144	1144	1144	1144	1144	1144	1144
Log-Lik.	-1649.717	-507.675	-339.79	-365.512	-280.597	-274.073	-621.716

Note: Redoes table 2 with the measure of horizontal inequality of Houle (9). This dataset includes only democracies. All models are ran with *STATA*. The *Former French Colony* is dropped from Models 3-4 due to lack of variation. Model 1 is ran using Ordinary Least Squares (with the command *reg*) and models 2-7 using Probit estimations (with the command *probit*). All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S8: Determinants of Social Unrest – Excludes Observations with Horizontal Inequality values below the 5th Percentile of the Distribution.

	Dependent Variables						
	Index	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged DV	.490	.959	.987	.933	1.748	1.767	.745
	(.032)***	(.094)***	(.100)***	(.136)***	(.127)***	(.150)***	(.081)***
Spatial DV	.206	1.019	.636	1.123	.396	-.232	.802
	(.041)***	(.157)***	(.249)**	(.258)***	(.312)	(.229)	(.155)***
Horizontal Inequality	.460	.425	.178	.215	.571	.668	.573
	(.177)***	(.211)**	(.263)	(.278)	(.314)*	(.289)**	(.230)**
Rule of Law	-.191	-.200	-.307	-.029	-.225	-.138	-.160
	(.067)***	(.099)**	(.098)***	(.116)	(.104)**	(.094)	(.080)**
Conformity	.218	.062	.228	.263	.369	.306	.263
	(.111)**	(.142)	(.153)	(.204)	(.174)**	(.186)*	(.132)**
Respect for Institutions	-.029	-.014	-.180	-.026	.173	.150	-.119
	(.099)	(.146)	(.137)	(.216)	(.165)	(.138)	(.120)
Number of Groups	.019	.016	.018	.011	.019	.004	.035
	(.005)***	(.009)*	(.009)**	(.008)	(.006)***	(.009)	(.005)***
Former British Colony	.079	.251	.241	.302	-.031	-.244	.122
	(.131)	(.153)	(.153)	(.175)*	(.192)	(.199)	(.161)
Former French Colony	.028	-.005	.059	.054	.238	-.053	-.109
	(.083)	(.092)	(.218)	(.176)	(.174)	(.160)	(.120)
Polity Score	.019	.012	.035	.042	.020	.005	.016
	(.008)**	(.011)	(.011)***	(.013)***	(.012)*	(.012)	(.009)*
Polity Score sq.	-.002	-.002	-.002	-.0002	-.004	-.002	-.003
	(.002)	(.002)	(.002)	(.003)	(.003)	(.003)	(.002)*
Ethnic Fractionalization	-.035	.030	-.228	-.455	.129	-.049	-.176
	(.167)	(.245)	(.243)	(.326)	(.287)	(.264)	(.220)
GDP pc (logged)	.215	.221	.081	-.022	.302	-.067	.344
	(.051)***	(.076)***	(.079)	(.091)	(.068)***	(.078)	(.066)***
Growth	-.003	-.003	-.008	-.009	.002	-.010	-.009
	(.003)	(.005)	(.006)	(.008)	(.008)	(.006)*	(.005)**
N	1791	1791	1791	1791	1791	1791	1791
Log-Lik.	-2581.922	-836.117	-567.402	-543.961	-495.836	-439.067	-988.139

Note: Redoes table 2 without observations with horizontal inequality values below the 5th percentile of the distribution. All models are ran with *STATA*. Model 1 is ran using Ordinary Least Squares (with the command *reg*) and models 2-7 using Probit estimations (with the command *probit*). All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S9: Determinants of Social Unrest – Excludes Observations with Horizontal Inequality values above the 95th Percentile of the Distribution.

	Dependent Variables						
	Index	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lagged DV	.488	.974	1.012	.972	1.756	1.766	.705
	(.033)***	(.099)***	(.102)***	(.135)***	(.122)***	(.153)***	(.076)***
Spatial DV	.222	1.049	.554	1.183	.377	-.164	.813
	(.040)***	(.156)***	(.249)**	(.278)***	(.312)	(.227)	(.162)***
Horizontal Inequality	.542	.522	.327	.502	.597	.816	.626
	(.161)***	(.205)**	(.270)	(.287)*	(.322)*	(.253)***	(.219)***
Rule of Law	-.187	-.231	-.297	.012	-.211	-.105	-.195
	(.066)***	(.101)**	(.099)***	(.120)	(.102)**	(.093)	(.082)**
Conformity	.211	.033	.261	.232	.457	.258	.227
	(.117)*	(.144)	(.161)	(.207)	(.194)**	(.189)	(.141)
Respect for Institutions	-.029	-.004	-.140	-.081	.248	.061	-.109
	(.096)	(.145)	(.146)	(.217)	(.170)	(.145)	(.120)
Number of Groups	.017	.015	.017	.011	.017	.002	.033
	(.005)***	(.009)*	(.009)*	(.007)	(.007)**	(.009)	(.005)***
Former British Colony	.116	.364	.225	.377	-.079	-.252	.208
	(.129)	(.149)**	(.152)	(.178)**	(.201)	(.202)	(.168)
Former French Colony	.030	.094	.070	.129	.176	-.106	-.069
	(.087)	(.095)	(.220)	(.174)	(.195)	(.164)	(.119)
Polity Score	.018	.014	.035	.048	.022	.0004	.015
	(.008)**	(.012)	(.011)***	(.013)***	(.012)*	(.012)	(.009)
Polity Score sq.	-.001	-.001	-.002	-.0003	-.003	-.001	-.002
	(.002)	(.002)	(.002)	(.003)	(.002)	(.003)	(.002)
Ethnic Fractionalization	-.162	-.091	-.310	-.638	-.118	-.265	-.262
	(.155)	(.240)	(.251)	(.341)*	(.267)	(.240)	(.217)
GDP pc (logged)	.190	.248	.061	-.048	.263	-.159	.351
	(.057)***	(.079)***	(.087)	(.098)	(.084)***	(.081)**	(.073)***
Growth	-.005	-.003	-.011	-.009	-.0007	-.010	-.012
	(.003)	(.005)	(.006)*	(.009)	(.008)	(.005)**	(.005)**
N	1788	1788	1788	1788	1788	1788	1788
Log-Lik.	-2544.426	-796.964	-553.51	-510.585	-479.314	-422.337	-979.779

Note: Redoes table 2 without observations with horizontal inequality values above the 95th percentile of the distribution. All models are ran with *STATA*. Model 1 is ran using Ordinary Least Squares (with the command *reg*) and models 2-7 using Probit estimations (with the command *probit*). All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S10: Determinants of Social Unrest – Prais–Winsten Regressions

	Dependent Variables						
	Index	Riot	Assass.	Strike	Guerrilla	Revol.	Demonst.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Spatial DV	.269	.257	.104	.225	.018	-.078	.286
	(.047)***	(.047)***	(.058)*	(.065)***	(.051)	(.060)	(.048)***
Horizontal Inequality	.891	.171	.087	.072	.175	.192	.245
	(.277)***	(.068)**	(.064)	(.051)	(.103)*	(.077)**	(.083)***
Rule of Law	-.322	-.082	-.079	-.022	-.071	-.012	-.073
	(.115)***	(.035)**	(.024)***	(.026)	(.034)**	(.027)	(.031)**
Conformity	.441	.011	.067	.028	.131	.088	.103
	(.213)**	(.054)	(.034)**	(.045)	(.057)**	(.046)*	(.058)*
Respect for Institutions	-.060	.001	-.031	.008	.053	.029	-.052
	(.175)	(.057)	(.031)	(.050)	(.057)	(.045)	(.046)
Number of Groups	.033	.006	.005	.001	.007	-.0003	.013
	(.012)***	(.004)*	(.004)	(.002)	(.003)**	(.003)	(.002)***
Former British Colony	.118	.112	.040	.066	-.034	-.113	.055
	(.247)	(.064)*	(.040)	(.050)	(.070)	(.056)**	(.072)
Former French Colony	-.006	.015	.006	.017	.061	-.061	-.050
	(.148)	(.035)	(.063)	(.041)	(.078)	(.058)	(.048)
Polity Score	.026	.004	.009	.008	.007	-.0004	.004
	(.013)*	(.004)	(.002)***	(.004)**	(.004)*	(.003)	(.004)
Polity Score sq.	-.003	-.0008	-.0005	.0003	-.001	-.0002	-.001
	(.003)	(.0007)	(.0005)	(.0005)	(.0006)	(.0007)	(.0008)
Ethnic Fractionalization	-.182	-.003	-.091	-.109	-.010	.011	-.096
	(.308)	(.096)	(.062)	(.090)	(.096)	(.072)	(.088)
GDP pc (logged)	.316	.093	.025	-.008	.078	-.041	.138
	(.097)***	(.027)***	(.021)	(.017)	(.028)***	(.024)*	(.028)***
Growth	-.005	-.001	-.002	-.001	.0003	-.001	-.003
	(.003)	(.001)	(.001)*	(.0009)	(.001)	(.0007)	(.001)**
Durbin-Watson statistic	2.066	1.993	1.982	1.938	2.024	2.036	1.985
N	1889	1889	1889	1889	1889	1889	1889
Log-Lik.	-2701.213	-875.746	-424.102	-349.013	-269.209	-150.441	-1086.776

Note: Redoes table 2 using Prais–Winsten Regressions. All models are ran with *STATA* using the command *prais*. Lagged dependent variables are dropped. All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S11: Determinants of Social Unrest – Detrended Data

Spatial DV	.185
	(.038)***
Horizontal Inequality	1.336
	(.266)***
Rule of Law	-1.321
	(.342)***
Conformity	1.754
	(2.334)
Respect for Institutions	-.599
	(.999)
Polity Score	-.003
	(.020)
Polity Score sq.	.004
	(.002)**
GDP pc (logged)	-1.382
	(.822)*
Growth	.003
	(.003)
N	1814
Log-Lik.	-2953.561

Note: Redoes Model 1 of Table 2 detrended data. Ran with *STATA*, using Ordinary Least Squares (command *reg*). Variables that are time-invariant are dropped. All independent variables are lagged. Robust standard errors clustered by country in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table S10, we report Durbin-Watson statistics. Durbin-Watson statistics range can range from 0 to 4, where 2 indicates no serial correlation. In the models, the Durbin-Watson statistics range from 1.938 to 2.066, indicating that there is no serial correlation at the 5% level of statistical significance.

Second, in Table S11, we follow Turchin and redo Model 1 of Table 2 with detrended data (19). We cannot do the same for the other models of Table 2 because they use binary dependent variables. Also, all time-invariant variables are dropped from the analysis (including the number of ethnic groups). Horizontal inequality continues to fuel social unrest, while the rule of law reduces it. The effect of conformity remains positive but falls out of statistical significance, probably because values change slowly in time and are unlikely to have an immediate effect on social unrest. The residuals associated with Model 1 of Table 2 are shown in Figure S2. We cannot plot the residuals for the other models because they are tested using nonlinear estimation and the dependent variables are binary.

Part 3. Additional numerical results

The graphs shown here (http://neko.bio.utk.edu/∼sergey/Unrest/summary.html) illustrate additional simulation results for varying parameters n, b, ε and λ. The values of the first three parameters are shown under each graph. The graphs are arranged in 4 sections corresponding to $\lambda = 5, 10, 20$ and ∞ which are specified at the beginning of each section. There are 4 graphs in each row corresponding to 4 independent runs of the model (out of 100 runs done for obtaining statistics). Other parameters are the same as in Figure 2 of the main text.

References

[1] J.K. Goeree, C.A. Holt, and T.R. Palfrey. *Quantal Response Equilibrium: A Stochastic Theory of Games*. Princeton University Press, Princeton, NJ, 2016.

[2] M. W. Macy and A. Flache. Learning dynamics in social dilemmas. *Proceedings of the National Academy of Sciences USA*, 99:7229–7236, 2002.

[3] S. Gavrilets. Collective action problem in heterogeneous groups. *Philosophical Transactions of the Royal Society London B*, 370:20150016, 2015.

[4] J. Hofbauer and K. Sigmund. *Evolutionary games and population dynamics*. Cambridge University Press, Cambridge, 1998.

[5] Arthur S Banks and Kenneth A Wilson. Cross-National Time-Series Data Archive, 2013.

[6] Alberto Alesina, Stelios Michalopoulos, and Elias Papaioannou. Ethnic Inequality. *Journal of Political Economy*, 124(2):428–488, apr 2016.

[7] Lars-Erik Cederman, Kristian Skrede Gleditsch, and Halvard Buhaug. *Inequality, Grievances, and Civil War*. Cambridge University Press, Cambridge, 2013.

[8] Carla Canelas and Rachel M. Gisselquist. Horizontal Inequality as an Outcome. *Oxford Development Studies*, 46(3):305–324, jul 2018.

[9] Christian Houle. Ethnic inequality and the dismantling of democracy: a global analysis. *World Politics*, 67(3):469+, JUL 2015.

[10] Carla Canelas and Rachel M. Gisselquist. Horizontal inequality and data challenges (vol 143, pg 157, 2019). *Social Indicators Research*, 145(3, SI):969–984, OCT 2019.

[11] Daniel Kaufmann, Aart Kraay, and Massimo Mastruzzi. The worldwide governance indicators: Methodology and analytical issues. *Hague Journal on the Rule of Law*, 3(2):220–246, jun 2011.

[12] WVS. World Value Survey - What We Do. *http://www.worldvaluessurvey.org/WVSContents.jsp*, 2019.

[13] EVS. European values study. *http://www.europeanvaluesstudy.eu/page/where-to-get-the-data-survey-2008.html*, jan 2011.

[14] Ronald. Inglehart and Christian Welzel. *Modernization, cultural change, and democracy: the human development sequence*. Cambridge University Press, Cambridge, 2005.

[15] Andreas Wimmer, Lars-Erik Cederman, and Brian Min. Ethnic Politics and Armed Conflict: A Configurational Analysis of a New Global Data Set. *American Sociological Review*, 74(2):316–337, 2009.

[16] Cristina Bodea, Ibrahim Elbadawi, and Christian Houle. Do civil wars, coups and riots have the same structural determinants? *International Interactions*, 43(3):537–561, 2017.

[17] World Bank. World Development Indicators, 2018.

[18] Jeffrey Wooldridge. *Econometric Analysis of Cross Section and Panel Data*.

[19] P. Turchin. Fitting dynamic regression models to seshat data. *Cliodynamics*, 9(1), 2018.