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# Cooperating with the future

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**Overexploitation of renewable resources today has a high cost on the welfare of future generations[1–5]. Unlike in other public goods games[6–9], however, future generations cannot reciprocate actions made today. What mechanisms can maintain cooperation with the future? To answer this question, we devise a new experimental paradigm, the 'Intergenerational Goods Game'. A line-up of successive groups (generations) can each either extract a resource to exhaustion or leave something for the next group. Exhausting the resource maximizes the payoff for the present generation, but leaves all future generations empty-handed. Here we show that the resource is almost always destroyed if extraction decisions are made individually. This failure to cooperate with the future is driven primarily by a minority of individuals who extract far more than what is sustainable. In contrast, when extractions are democratically decided by vote, the resource is consistently sustained. Voting[10–15] is effective for two reasons. First, it allows a majority of cooperators to restrain defectors. Second, it reassures conditional cooperators[16] that their efforts are not futile. Voting, however, only promotes sustainability if it is binding for all involved. Our results have implications for policy interventions designed to sustain intergenerational public goods.**

Providing for future generations is central to the survival of genes, families, organizations, nations and the global ecosystem[1–5]. Yet providing for the future poses a challenge, as it requires making sacrifices today. Institutions can play an important role in promoting such cooperative behaviour among large groups of people. Traditionally, institutional designers have assumed that people are rational and purely self-interested, and proposed incentives that induce selfish people to cooperate[17–19].

In recent years, however, a large body of evidence has demonstrated that many people are not purely selfish[5,20–25]. Here we consider the implications of these 'social preferences' for designing institutions that promote sustainability and intergenerational cooperation. We demonstrate that democracy can be a powerful institution for harnessing social preferences: although selfish people would vote for over-exploitation of resources, voting allows a pro-social majority to override a selfish minority (see Supplementary Information section 1 for further discussion).

To test this, we introduce a laboratory model of cooperating with the future—the Intergenerational Goods Game (IGG)—that builds on previous work using Public Goods Games[7–9], Common Pool Resource games[6,11] and Threshold games[4,26,27]. In these other games, selfishness creates social efficiency losses for the other members of one's group. In contrast, the IGG is designed such that selfishness instead negatively affects subsequent groups.

In our IGG experiments, individuals form groups of five, which we refer to as generations. The first generation is endowed with a common pool of 100 units and each individual can extract between 0 and 20 units from the pool. If the total percentage of units extracted from the pool is at or below a commonly known extraction threshold, $T$, the pool will renew to 100 units for the next generation. If, however, the percentage extracted is above $T$, the pool is exhausted and all future generations receive no payoff (Fig. 1). After each generation, another generation occurs with probability $\delta$, and with probability $1-\delta$ the game ends: the discount factor $\delta$ models the extent to which the current generation values the next generation (see Supplementary Information section 2 for further experimental details).

In the game theoretic tradition, the IGG framework is a great simplification relative to real-world intergenerational cooperation. For discussion of important aspects of intergenerational transfer which the IGG does not yet incorporate, as well as relation of our work to previous results on intergenerational transfer, see Supplementary Information section 3.

To explore behaviour in the IGG, we began with an 'unregulated' treatment: each group member individually chooses how many units to extract from the pool. We initialized 20 unregulated IGGs and passed each game's pool across a series of generations with a discount factor of $\delta = 0.8$ (leading to an expected game length of five generations). For the pool to be replenished, each generation had to extract 50 units or less ($T = 50\%$). Thus, the socially efficient extraction (or 'fair share') was 10 units per individual on average. We focus on symmetric strategies and refer to individuals who extracted 10 or fewer units as cooperators, and those who extracted more than 10 units as defectors.

We found that a large majority of individuals cooperated (68%), in line with previous studies using non-student populations[23–25]. Despite their good intentions, however, only 4 of the 18 games continuing on to a second generation had their pools sustained. These losses in sustainability compounded quickly over time: in the third generation, the number of refilled pools was down to two, and not a single refilled pool was available to the fourth generation (Fig. 2a). Notably, in most groups, only a minority of defectors was responsible for the exhaustion of the resource.

To address this sustainability failure, we introduce an institution that is firmly established in large parts of the world: democracy. Each group member votes for their generation's extraction level, and the median vote is extracted by all players. Well studied by economists and political scientists[10–15], this 'median voting' rule guarantees socially optimal outcomes in a standard Public Goods Game, even with perfectly self-interested actors: the payoff-maximizing vote is full cooperation[14,15]. In the IGG, however, this is not true: because the current group does not reap the benefits of cooperation, selfish players would vote to deplete the resource fully. From a traditional 'public choice' perspective based on rational self-interest, therefore, median voting is not attractive for promoting sustainability. If, however, enough players have social preferences, voting may be able to support sustainability in the IGG by allowing pro-social players to rein in selfish players. Thus a 'behavioural public choice theorem'[12–14] might favour median voting; see Supplementary Information section 1 for further discussion.

To explore the effects of median voting, we initialized another 20 IGGs using $\delta = 0.8$ and $T = 50\%$, and applied the voting rule. We found a dramatic increase in sustainability (Fig. 2b): all 20 common pools were sustained across all generations (unregulated versus voting: linear probability model (LPM) predicting pool sustainability at the generation level, $P < 0.001$; see Supplementary Information section 4 for statistical details).

Next we asked how robust the voting mechanism is to variation in the discount factor, $\delta$, and the extraction threshold, $T$. In the experiments described above, there was an 80% chance that a future generation would exist ($\delta = 0.8$) and individuals had to sacrifice half of their possible payoff

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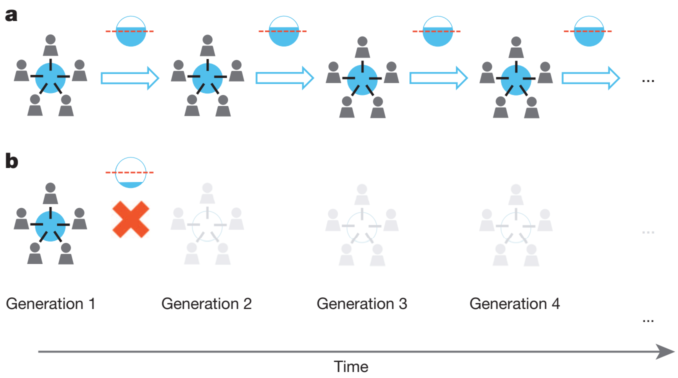

**Figure 1 | An illustration of the Intergenerational Game (IGG).** In each generation, a group of 5 people makes a decision (individually or according to an institutional rule) about their level of extraction from a common resource. **a**, If Generation 1's extractions do not violate the commonly known threshold, the resource refills and the same dilemma is presented to Generation 2. After each generation, another generation occurs with probability $\delta$. **b**, If at any point the threshold requirement is not met, the resource does not renew and future generations receive no payoff. Maximal social welfare is achieved if no generation ever violates the threshold requirement by extracting too much from the common resource.

to extract a 'fair share' ($T = 50\%$). To assess robustness, we examined the effectiveness of voting in two treatments using lower $\delta$ values ($\delta = 0.7$ and $\delta = 0.6$, creating fewer future generations), and two other treatments using lower $T$ values ($T = 40\%$ and $T = 30\%$, leading to a higher cost of cooperation). Each treatment again started with 20 pools.

We found that voting remained largely effective in promoting sustainability under these more adverse conditions (Fig. 2c). Although sustainability did vary significantly with $\delta$ (LPM, $P = 0.037$) and $T$ (LPM, $P < 0.001$), the size of these effects was relatively small: decreasing $\delta$ or $T$ by 0.1 decreases the probability of a pool being sustained by 4.6% or 14.6%, respectively. Moreover, under all conditions tested, voting led to much higher levels of sustainability than the original unregulated IGG (LPM, $P < 0.001$ for all comparisons).

The success of voting is driven by two factors. First, the decision-making power differs in the voting and unregulated institutions (Fig. 3a). In the voting institution, a majority of three cooperators who propose 10 unit extractions can overrule two defectors who propose 20 units. In contrast, if decisions are made at the individual level, a single defector can tip the balance of a group. In other words, voting allows a majority of cooperators to restrain a minority of defectors.

The second reason for the success of voting pertains to the psychology of social preferences. Median voting addresses the fears of players who care about future generations but worry that others (now or later) will exhaust the pool (that is, future-oriented 'conditional cooperators'[16]): as the outcome of the vote is applied to all players, everyone within a generation receives the same payoff and no one risks feeling like they have been taken advantage of. This, in turn, further increases the probability that a cooperative majority is formed and the pool is sustained, both in the current generation and in the future. Figure 3b is consistent with this assessment: the fraction of cooperators was 20% larger under voting than unregulated (LPM, $P < 0.001$).

Both of these factors predict that voting is only successful if everyone is bound by the outcome: a partial implementation[15] provides an opportunity both for defectors to derail sustainability, and for potential cooperators to switch to defection out of fear that others will over-exploit.

We test this prediction by introducing a 'partial voting' treatment (another 20 pools, again using $\delta = 0.8$ and $T = 50\%$). Three of the five people in each generation are bound by the decision of a median vote among themselves. The other two people are not informed of the vote's outcome, and decide freely how much to extract. The sum of all five extractions is then compared to the extraction threshold $T$.

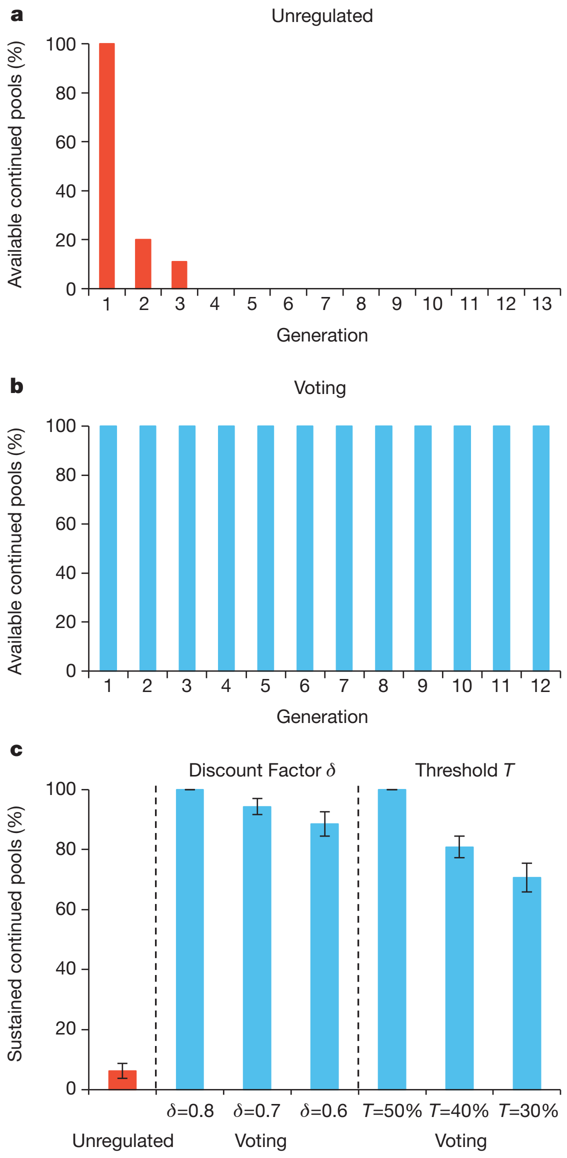

**Figure 2 | Solving the (intergenerational) 'tragedy of the commons' through an institutional design. a**, When decisions are made at the individual level, the availability of the common pools drastically decreases over time; $n = 480$. **b**, The introduction of a democratic voting institution strikingly improves sustainability; $n = 370$. **c**, Decreasing the discount factor from $\delta = 0.8$ to $\delta = 0.7$ ($n = 355$) or $\delta = 0.6$ ($n = 305$) while holding $T = 50\%$, or the extraction threshold from $T = 50\%$ to $T = 40\%$ ($n = 600$) or $T = 30\%$ ($n = 460$) while holding $\delta = 0.8$, increases the temptation to defect. Nonetheless, much less is extracted under median voting compared to the unregulated baseline. Error bars indicate standard errors of the mean.

As predicted, the partial voting institution was significantly less successful than the full voting institution (Fig. 4a, LPM, $P < 0.001$). This point was supported by bootstrapping simulations: of 10,000 pools created by randomly sampling participant decisions each generation, only 1.5% of available pools were sustained after 15 generations under partial voting, compared to 84% under full voting; see Extended Data Fig. 1 and Supplementary Information section 5 for details. We conclude that, for voting to effectively manage sustainability, it must be binding for all decision-makers.

In this paper, we have introduced a new laboratory model for cooperation across generations, the Intergenerational Goods Game (IGG). We have shown that in the absence of regulation, a minority of selfish players consistently deplete available resources. By implementing median voting, however, this negative outcome can be prevented—but only if all players are bound by the outcome of the vote. Votes that are only

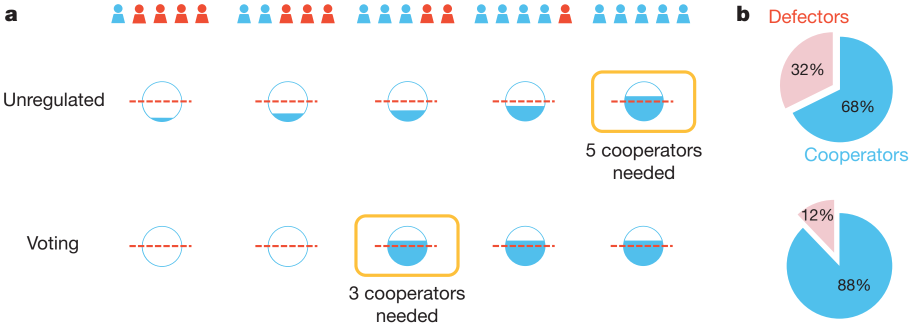

**Figure 3 | The voting institution is robust to extreme decision-makers and thereby increases cooperative behaviour. a**, The pivotal decision-maker in the voting institution is different from the unregulated institution. For instance, assume that $T = 50\%$ and that a cooperator and a defector always extract 10 and 20 units, respectively. The unregulated institution is vulnerable to extreme decision-makers, whereas the voting institution is robust to a minority of defectors. This, in turn, bolsters the decision of those who are predisposed towards cooperation but fear to be exploited (for example, future-oriented 'conditional cooperators'). **b**, This leads to an increase of cooperators in the voting institution ($n = 370$) over the unregulated institution ($n = 480$).

partially binding, such as the international Kyoto protocol, have little power.

More generally, our results emphasize the importance of institutional designers moving away from the assumption of universal self-interest. We extend the 'behavioural public choice theorem'[12–14] by demonstrating how voting can allow a majority of pro-social individuals to override a purely selfish minority, leading to costly group-level cooperation with future generations. Real-world data are consistent with this suggestion: countries that are more democratic also have more sustainable energy policies (combining data for 128 countries from *The Economist* Democracy Index and World Energy's Energy Sustainability Index, $P < 0.001$, $R^2 = 0.36$; robust to controlling for GDP, Gini index, population size, literacy rate, unemployment rate, life expectancy and level of corruption; see Extended Data Fig. 2 and Supplementary Information section 6 for details). Policy makers can do much to promote the public good by using a behavioural approach that is informed by a more accurate understanding of human psychology[14,28–30]. Many citizens are ready to sacrifice for the greater good. We just need institutions that help them do so.

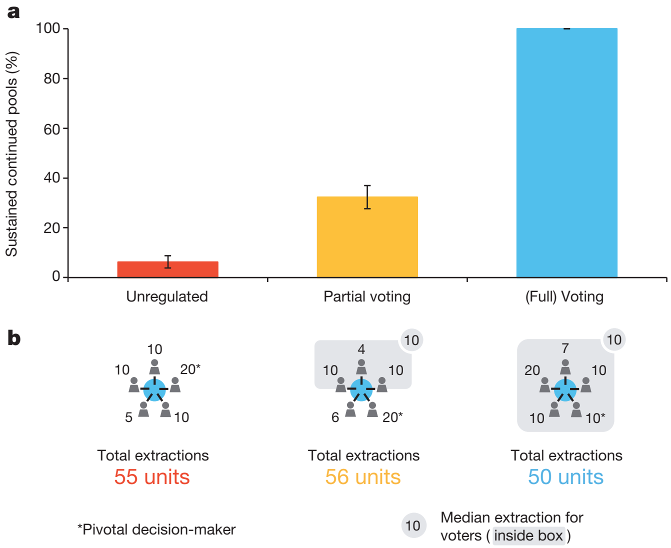

**Figure 4 | Voting must be binding for all players in order to achieve high levels of sustainability. a**, In a partially implemented voting institution ($n = 495$), three of the individuals are bound to a vote while the other two can extract at will. A partially implemented voting institution is not robust to a minority of defectors and also cannot reassure conditional cooperators. Thus, partial voting fails to lead to sustainable outcomes. **b**, Three real sets of decisions from our data demonstrate a consequence of the pivotal extractor outside the voting group.

**Online Content** Methods, along with any additional Extended Data display items and Source Data, are available in the online version of the paper; references unique to these sections appear only in the online paper.

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**Supplementary Information** is available in the online version of the paper.

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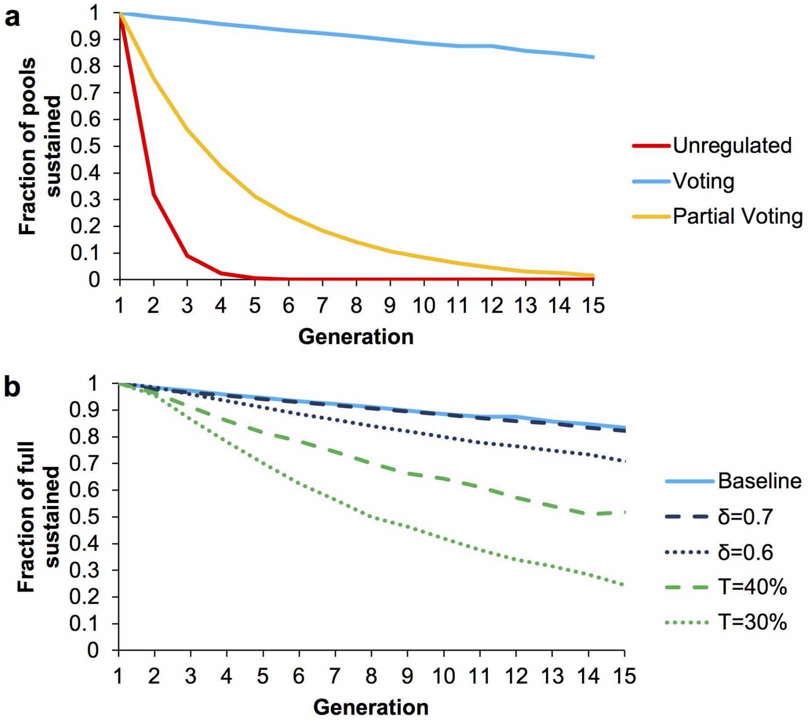
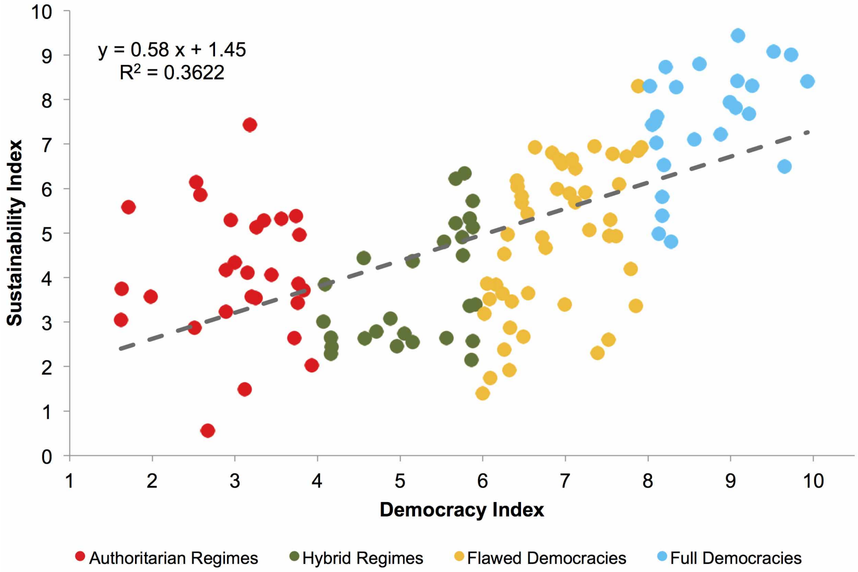


**Extended Data Figure 1 | Bootstrapping simulations demonstrate the robustness of full voting and the failure of partial voting.** We address sources of noise in the sequence of events that occurred in our experiment by conducting a set of computer simulations using the data generated by our participants. We randomly sample (with replacement) a series of generations of participant decisions, and calculate the fraction of those generations in which the pool was refilled. For each condition, we simulate 10,000 pools (or 1,000,000 pools if $\delta < 0.8$) for 15 generations. **a**, Simulated data for the unregulated, full voting and partial voting conditions show that full voting is by far the most successful at sustaining the pool. **b**, Simulated data for the $T = 40\%$, $T = 30\%$, $\delta = 0.7$ and $\delta = 0.6$ conditions shows that reducing $\delta$ has only a small effect, and although reducing $T$ does undermine sustainability, the effect is much less striking than that of unregulated or partial voting despite the higher value of $T$ in these less-regulated conditions.



**Extended Data Figure 2 | Countries with more democratic governments have more sustainable energy policies.** Energy sustainability index (as measured by the World Energy organization) is shown as a function of the democracy index (as measured by *The Economist* Intelligence Unit) for $n = 128$ countries. A strong positive association is clearly visible, and this association is robust to controlling for gross domestic product (GDP), Gini index, population size, literacy rate, unemployment rate, life expectancy and level of corruption. Thus we provide preliminary empirical support for the role of democracy in promoting sustainability outside the laboratory. We adopt the colouring and naming scheme from *The Economist* Intelligence Unit's classification of regimes.