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The bioeconomics of planetary energy transitions—a theoretical note

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Abstract

Evidence is mounting that unprecedented economic growth experienced by human societies over the past two centuries has induced a state of crisis for the Earth's ecological systems—a crisis that threatens human society's existence and heightens the risk of violent conflict. This article presents a simplified model of bioenergetic evolution on a planetary level. It examines human energy exploitation based on three strategies concerning the natural world: (1) predation, (2) competition, and, more cursorily, (3) mutualism. Predation involves the capture of energy pre-processed by the biotic community (living organisms sharing a common environment). Competition involves appropriating lands to capture solar-generated energy, edging the biotic community out. Mutualism involves engaging the biotic community in a mutualistic effort to harvest energy (and discard energy waste in the form of heat) outside of the planetary system. The model implies that, theoretically, substantial government investment in Earth-based solar generation may be required to effect a planetary energy transition to avert ecological collapse. The model suggests that this transition is not likely to happen automatically as a function of substitution by individual economic actors prior to ecological collapse; rather, it requires top-down coercive and/or incentive measures applied by government.

There is an increasing body of evidence indicating that human societies' unprecedented economic growth in the last 200 years is creating an ecological crisis. Many of the public goods provided by ecological systems—fresh water, clean air, abundant fisheries, nutritious soils, low sea levels, and moderate weather, to name a few—are increasingly at risk. Their failure poses existential threats to the societies humans have collectively built over millennia, and heightens the risk of violent conflict through multiple causal pathways.[1]

The human economy is increasingly recognized as a subsystem of a much more sophisticated energy and resource allocation mega-system—that of Earth's biosphere. Both can be viewed, in the most general terms, as mechanisms for maximizing entropy, though the human+ [2] economy is more highly entropic than the pre-human biosphere. In other words, the addition of a modern human economy to the biosphere requires more energy and generates more heat.[3] This observation harmonizes with recent work in biophysics, suggesting that entropy is a primary selector for self-replicating molecules, and therefore that the evolution of life is "as unsurprising as rocks rolling downhill."[4] Economics increasingly recognizes a mutualism between the human and ecological systems. Economists have been used to analyzing optimal stewardship of "natural resources" and the opportunity costs associated with the privation

1 E.g., inter-group fighting over scarce resources, conflicts between environmental migrants and would-be host communities, popular revolts against governments perceived as corrupt or ineffectual in reducing environmental risks, etc.

2 Human+: Numerous thinkers have been engaged in the process of enlarging their respective, anthropocentric disciplines' fields of view to include non-human biotic life, electronic life (e.g., artificial intelligence), and even collectivities of organisms and their non-organic environments, such as ecosystems and biomes. These thinkers include Eduardo Kohn (2013), Craig Holdrege (2013), Suzanne Simard (2021), Gregory Bateson (2000[1972]), Nick Bostrom (2014), James Lovelock (2020), Donna Harraway (2016), and Kevin Kelly (2010).

3 Lovelock (2020).

4 England, quoted in Wolchover (2014). See England (2015).

Modelling human energy exploitation based on three strategies (predation, competition and mutualism), indicates that substantial government investment in Earth-based solar generation may be required to effect a planetary energy transition to avert ecological collapse and widespread conflict. It also raises doubt that this transition will happen automatically as a function of substitution by individual economic actors prior to ecological collapse; rather, it may require top-down coercive and/or incentive measures applied by government. Managing social and political expectations in this scenario is of the utmost importance.

of "environmental services." But given the scope and scale of ecological collapses around the globe, bioeconomics increasingly presumes the indirect value of ecological systems[5] in a way reminiscent of Kenneth Boulding's ecological economics[6].

This new, wider bioeconomic conception tends to call into question the traditional distinction between the human and nonhuman worlds. It may even challenge the utilitarian philosophy undergirding economics, to the extent that the utility of nonhumans, or indeed that of collectivities and other non-individuals (e.g., whole biomes or habitats) is validated. Economists studying peace and conflict dynamics have long relied (often unthinkingly) on the human–nonhuman distinction when analyzing strategies for reducing intra-human forms of violent predation; human predation of the nonhuman world was simply not normally considered violence at all.[7] All the institutional guarantees of property security, contract enforcement, and indeed bodily security and freedom of choice deemed requisite for a well-functioning market economy[8] simply did not pertain to animals, much less to other biota: plants, fungi, bacteria, viruses, or entire symbiotic communities comprising a rich admixture of them all. Rather, the latter could, and can, be owned and allocated as human "resources" and property. Of course, those institutional guarantees not only failed to apply to some humans—people of color and women—until relatively recently in many parts of the world, but even allowed for large segments of the human population to be bought and sold as property themselves. Indeed, the evolution of human rights functioned to include progressively more people as valid economic actors[9], while simultaneously hardening the human–nonhuman dichotomy. That dichotomy endures and structures our economic lives. It is older and more fundamental to modern life than any specifically "Western" conception of the cosmos, perhaps tracing its origins to all six of the so-called neolithic "cradles of civilization,"[10] and certainly manifesting in humanity's oldest recorded tale, *The Epic of Gilgamesh*. But while its origins exceed the scope of this article, its contours very much inform the present project.

This article presents a simplified model of bioenergetic evolution on a planetary level. It examines human energy exploitation based on three strategies concerning the natural world: (1) predation, (2) competition, and, more cursorily , (3) mutualism. These strategies are listed in this sequence to signal monotonically: (a) increasing overhead costs, (b) increasing returns at scale, and (c) decreasing negative environmental impacts per unit of energy harvested. Predation involves the capture of energy that has been pre-processed by the biotic community into a form amenable to human exploitation. Predation may take the form of hunting, timber harvesting, coal mining, petroleum pumping, or other types of energy appropriation. Competition involves appropriating lands (or sea surfaces) to capture solar-generated energy, edging the biotic community out of contention for associated solar energy or resources. Mutualism involves engaging the biotic community in a mutualistic effort to harvest energy (and discard energy waste in the form of heat) outside of the planetary system—a space-based solar energy harvesting model. This article demonstrates the logic of economic evolution from a predatory resource extraction model, to one based on so-called renewable

5 Brauer and McDougal (2020).
6 Boulding (1966).
7 Important works on "natural resources/ services" and violent conflict are too numerous to do justice by way of summarization, or even citation. Some prominent examples might include Homer-Dixon (1994); Le Billon (2001); Bannon and Collier (2003); Hsiang, Burke, and Miguel (2013); Humphreys (2005). Brauer (2009) is a notable exception.
8 Williamson (2000).
9 Choi-Fitzpatrick (2022 forthcoming).
10 Foster (2021).

resources, and on to a space-based model of energy harvesting and heat disposal. It employs a simple model to argue that the transition away from a predatory model of economic growth requires planning on a planetary scale—something a free market is not equipped to handle. In other words, it requires government intervention.

Economy as bioenergetics

Resource distribution is uneven, and energy is no exception to this rule. The amount of solar energy that reaches Earth represents just 5 of every 10 billion Joules of energy output by the Sun (or 0.00000000046% of the Sun's total radiant output). The biosphere captures a very small amount of the solar energy that happens to fall on the Earth. Around 29% of it is reflected back into space.[11] The remainder is absorbed by a combination of the atmosphere and surface of the planet. Of the tiny amount of solar output that falls on photosynthetic biotic life, just 3% is captured by (and used to make more) organic compounds, a tiny fraction of which are eventually transformed into the hydrocarbon chains that fuel the modern carbon economy that characterizes life after the invention of the steam engine.[12]

Of the embodied energy manifest in our ecosystems, humanity appropriates some portion for its own uses and benefits. From a physical point of view, energy is never "generated," but only captured, harvested, exploited. Depending on the quantity appropriated, humanity may thereby imperil the products of natural services that it has come to depend on: fresh water, moderate weather, fertile soil, abundant fisheries, to name a few. As mentioned above, this article draws a distinction between the economy's predatory appropriation of pre-processed embodied energy, and its appropriation of land to process solar energy into usable forms without harnessing the biotic community to do so. We typically deem the latter approach to be "sustainable," but this article argues that it is merely a necessary intermediary step toward greater sustainability. If humanity were collectively to draw its energy needs from the Sun in ways that did not predate the natural world, those energy inputs into the human+ economy might be deemed to be truly exogenous to the planetary system. Such strategies would therefore also require an equally exogenous disposal of energy waste (i.e., heat). But they would require considerable investment, drawing on the previous, appropriative models of development. In this way, every economic advancement up to that point would nevertheless be considered part of a long "bootstrapping" phase of economic development.

We might graphically represent the three energy harvesting strategies in Figure 1A, 1B and 1C. Figure 1A depicts a bioenergetic pyramid in a predatory model of energy acquisition. Above some threshold, humanity is able to make use of the solar energy originally captured and preprocessed by other organisms. We might imagine that technology allows us to lower that threshold, appropriating for human consumption a greater part of the bioenergetic pyramid. Figure 1B depicts a model typically termed "sustainable energy"—harvesting solar (or solar-derived) energy by appropriating some portion of the planet's surface area (i.e., "competition"). It is worth noting that agriculture is itself a basic form of this model, albeit one that captures less solar energy per area in the form of food than a solar panel can store in a battery. It also bears noting that our current economy does a little of both 1A and 1B. Finally, Figure 1C depicts an extra-planetary expansion of solar harvesting capabilities. Such an expansion is deemed to be "cooperative" from the point of view of human–nonhuman relations: the biosphere continues to provide an environment conducive to human flourishing, and humanity in return reduces its ecological footprint.

11 Earth Observatory (2009).
12 Biello (2011).

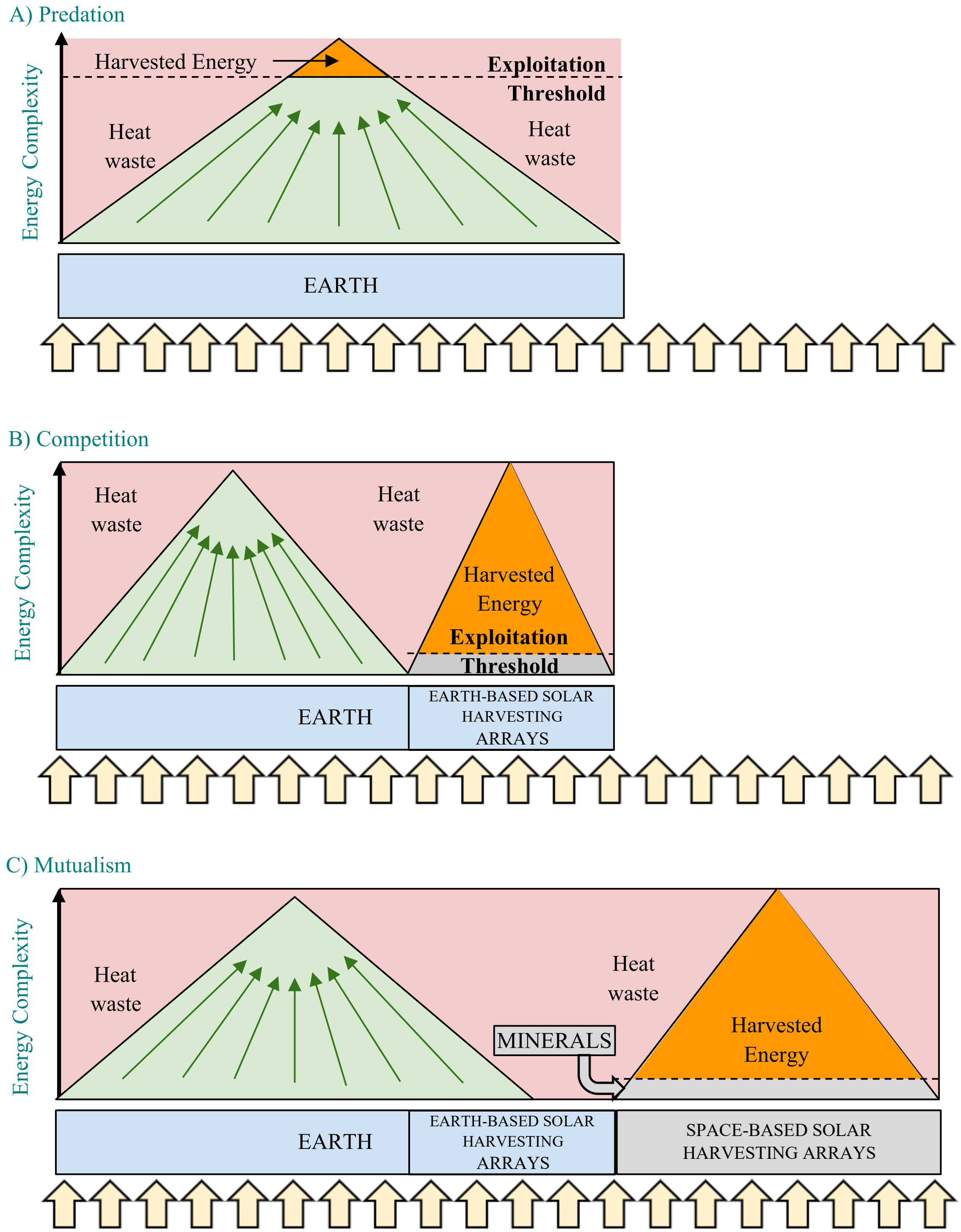

Figure 1: Three energy harvesting strategies: A) predation, B) competition, and C) mutualism

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Contextual framing

This study fills a gap in the energy transition literature, which is largely dominated either by quantitative scholars from the technical sub-field of energy economics, or by more qualitative policy scholars hailing from (international) political economy (IPE). Neither the methods, nor the attitude, of these two literatures often match. The empirical bioeconomic and energy economics literature tends, by necessity, to have small units of analysis, focusing on projects, programs, or municipalities (though exceptions exist, especially in computational modeling of the energy industry). The IPE literature tends to use the nation-state as its standard unit of analysis, albeit situated within the broader global context of "problems without borders." The former tends to be more optimistic, opening technically and, sometimes, financially or economically feasible pathways to "sustainability." It often studies outlier or otherwise idiosyncratic cases with an eye toward large-scale reproduction. The latter tends to be more pessimistic, dwelling on political realities that may subvert attempts to make use of those pathways.

The contemporary energy economics literature has emphases on three principal categories: sustainable energy economics, the technical and technological aspects of renewable energy generation and consumption, and estimating or modeling the environmental impacts of various energy production alternatives[13]. In the third category, for instance, energy use and associated emissions have been estimated as a result of a municipal energy transition in China undertaken during the Covid-19 pandemic, finding declines of 34% in energy use and 40% in CO2 emissions[14]. One strand of this literature arose in the context of the lukewarm reception of emissions reductions targets by national governments of the Global North in the first decades of the 21st century. It sought to study the role of the private sector and sub-national governments in advancing climate change mitigation and sustainable energy strategies, especially in the developing world[15]. While largely optimistic, this literature often makes appeals to national or international governments to improve markets for the growth of sustainable technologies by raising awareness and education levels, regulating the markets to exclude bad actors and disempower legacy monopolies that might raise entry costs, and extending credit and finance markets[16]. It should be noted that many of the computational economic models in energy economics rely on equilibrium analyses; some scholars have argued that such models have consistently underestimated the growth in renewable technologies, and that agent-based models are far more responsive to wholesale disruptions of industry, such as that introduced by solar "prosumers" (who both produce and consume energy). They argue that non-linearities and cumulative causation in the renewable sector's growth should make us much more optimistic about an automatic energy transition than equilibrium analyses might suggest.[17]

The political economy literature, as a general rule, identifies areas in which global capitalism has failed to respond to the exigencies posed by the climate and broader environmental crises[18]. These failings may be associated with political stakeholders representing entrenched economic interests from the fossil fuel economy. Such spoilers stand to lose out and therefore impede more efficient transitions[19]. Alternatively, they may find that the capitalism of the "sustainable energy" economy commits many of the same sins of the previous model. The neoliberal approach to energy transitions in Chile, for example, has been described as single-mindedly focused on rapid growth in the lithium mining sector[20]. Such an approach represents an immediate threat to local water sources. More profoundly, it rebuffs participatory development processes that would give value to the voices of those indigenous peoples whose ancestral lands are being mined. It also sits uneasily with the general notion of sustainable development as implying an end to

13 Chen, Xiong, Li, Sun, and Yang (2019).
14 Su and Urban (2021).
15 Agrawala *et al*. (2011); Pauw and Pegels (2013).
16 Raberto, Ozel, Ponta, Teglio, and Cincotti (2019); Yadoo and Cruickshank (2012).
17 Hoekstra, Steinbuch, and Verbong (2017).
18 Newell (2019, 2021).
19 As Baker, Newell, and Phillips (2014) describe in the case of South Africa
20 Furnaro (2019).

economic growth[21]. Given these critiques of undirected capitalism in the energy sector, as well as the importance that political economy tends to lend to the intercalation of industry and institutions of the state, it is perhaps not surprising that much of this literature highlights the role of national governments in pioneering and promulgating experimental policy avenues to effect clean energy transitions[22]. The preeminent role of national policies and governments is further reinforced by other inherent characteristics of the energy sector, including: High overhead costs associated with R&D, scaling, and human resources upgrading; massive complexity and uncertainty in the energy markets internationally; concurrently dynamic technological change; and myriad transition pathways[23].

In summary, then, we have one broad family of literature drawing from economics that is confident in an automatic energy transition driven by market forces (with some government market regulation in the neoclassical model). We have another, drawing from the IPE tradition, that believes in the necessity of government intervention to effect meaningful change (even as they remain skeptical about government's capacity to do so). However, neither literature grapples overmuch with the connection between technology and environmental degradation overall. To the extent that dynamics and non-linearities are considered, they are done so in modeling the human economy. The connection between bioenergetic environmental systems and the overlaying human economy is not usually made explicit as it was, for instance, in the famous 1972 (subsequently updated in 1992 and 2002) biologically informed *Limits to Growth* model[24]. This article provides a simple model to demonstrate that ecological collapse and the energy transition are intimately woven together. Moreover, it shows that there is an argument to be made from the economics side that top-down intervention may be required to effect it, due to nonlinearities not in economic growth patterns, but in the health of the underlying environment systems.

A model of the biotic system

We begin our model by recognizing that the energy captured by ecological processes is recycled through the system. Phytoplankton are consumed by zooplankton, which are in turn eaten by small crustaceans and fish, etc. Moreover, energy embodied in dead creatures is then recycled through the system via detritivores. The food chain—what Aldo Leopold called the "land pyramid," though of course it also applies to the oceans—is also a system of bioenergy allocation and reuse. This resource allocation system contains and conditions the resource allocation subsystem we call the economy. The proportion that gets reused in the biosphere we call α. We posit therefore that the total welfare of the nonhuman biosphere richness R will be modeled using the function:

(1a) $$R = X(1/(1-\alpha))$$

where X represents the quantity of solar radiation input into the biotic system. However, evolution also provides a mechanism through which the system can change and develop over time. Former evolutionary developments serve as the springboards for new developments permitting resource exploitation at scales, and in environments, previously unfeasible. The emergence of the first prokaryotes during the Archean Eon (4.0–2.5 billion years ago) permitted some 2.7 billion years ago the formation of eukaryotic cells, which combined and coordinated various prokaryotes as organelles. Similarly, single-celled eukaryotes were a prerequisite for the evolution of multicellular life about 600 million years ago. Because "higher" organisms often predate "lower" ones, and "lower" ones assist in the decomposition of "higher" ones, the development of a stratified bioenergetic system heightens the degree to which bioenergy is recycled within the biosphere. This kind of endogeneity we represent temporally such that the output of the system at a previous point in time conditions the recycling term for the present:

21 Daly (1999); Harraway (2016); Korten (1995); Raworth (2017); Schor (2010).
22 Arndt, Miller, Tarp, Zinaman, and Arent (2017).
23 Kern and Markard (2016).
24 Meadows, Randers, and Meadows (2004).

(2b) $R_2 = X(1/(1 - R_1\alpha))$

At equilibrium, we can solve for R to obtain:

(2) $R = (1 \pm \sqrt{1 - 4\alpha X})/2\alpha$

This relationship takes the shape of a horizontal parabola. Finally, along with Fujita, Krugman, and Venables (1999), we posit that α is proportional to R_1 up to some maximum point ā, after which no improvements on recycling can be made and when the previous equation is replaced simply by:

(3) $R = X(1/(1 - \bar{a}))$ if $\alpha > \bar{a}$.

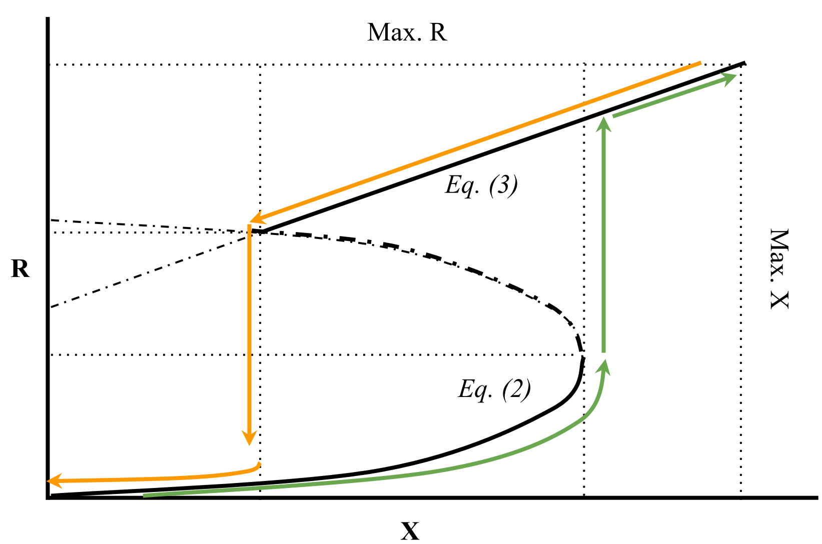

Figure 2: Biosphere richness (R) as a function of solar energy input (X)

Figure 2 encapsulates this model, with overlapping pooling equilibria (solid lines) connected by separating equilibria (dashed lines). This model demonstrates in simple terms what more complex ecological models have shown in less simple terms, namely: past a certain "sustain point," the biosphere is relatively resilient in the face of perturbations (here modeled as reductions in the amount of bioenergy allotted to it). However, past a certain "break point," the system will fall to dramatically lower levels of output. After such a collapse, the cost of repair to the system far exceeds the energy allowance that would have been required to avoid collapse. In other words, the model is not technically a function, as it can take on two potential values of R for given intermediate values of X, depending on whether X is increasing (see the green arrows in Figure 2) or decreasing (see the orange arrows in Figure 2).

All of this we describe as the system at equilibrium and, for our intents and purposes, in the absence of human intervention. Humans in this simplification are able to appropriate energy in two ways: first by direct predation of bioenergetic resources, earning them H_P, and second by appropriating land for solar harvesting, earning them H_L. We then define the marginal human bioenergetic "profits" derived from predation as:

(4) $H_P = (R_{max} - R_P) - s(R_{max} - R_P) = (1 - s)(R_{max} - R_P)$

where R_{max} is the maximum level of natural resources given X, R_P is the level of natural resources given P, and $s < 1$ is the degree to which humans receive natural services from the biosphere. The term $-s(R_{max} - R_P)$ then represents the opportunity costs of ecosystem destruction. Note that marginal returns are declining in predation level, and thus that the optimal solution will not be total predation, but rather some level of predation lower (perhaps just marginally) than that which would cause a collapse. However, given the high elasticity of R when $\alpha > \bar{a}$ $(1/(1 - \bar{a}))$, direct predation may lead toward the break point quite quickly.

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Likewise, we define the marginal human bioenergetic "profits" derived from land appropriation as:

(5) $$H_L = tL^{\gamma} - l - s(R_{max} - R_{X-L})$$

where L is the amount of land appropriated for energy production, $t \in (0,1)$ is a technological coefficient, $0 < \gamma < 1$ represents decreasing returns to scale, and l is an overhead cost for solar energy capture technology development. t represents the proportion of radiant energy that can be effectively utilized for human benefit; it is bounded between zero and unity in order to prevent the human economy from magically multiplying the amount of energy captured to more than was captured in the first place. Notice that the term denoting opportunity costs stemming from ecosystem destruction—for parsimony's sake, we assume that predation has no overhead costs; this is untrue, but predation overhead costs are generally much lower than the overhead costs of technologically sophisticated solar exploitation.

The results are depicted in Figure 3, where Figure 2 continues to occupy quadrant I, H_P occupies quadrant II (note that R_P is corresponds directly and negatively to R), and H_L occupies quadrant IV (again, with L corresponding directly and negatively to X).

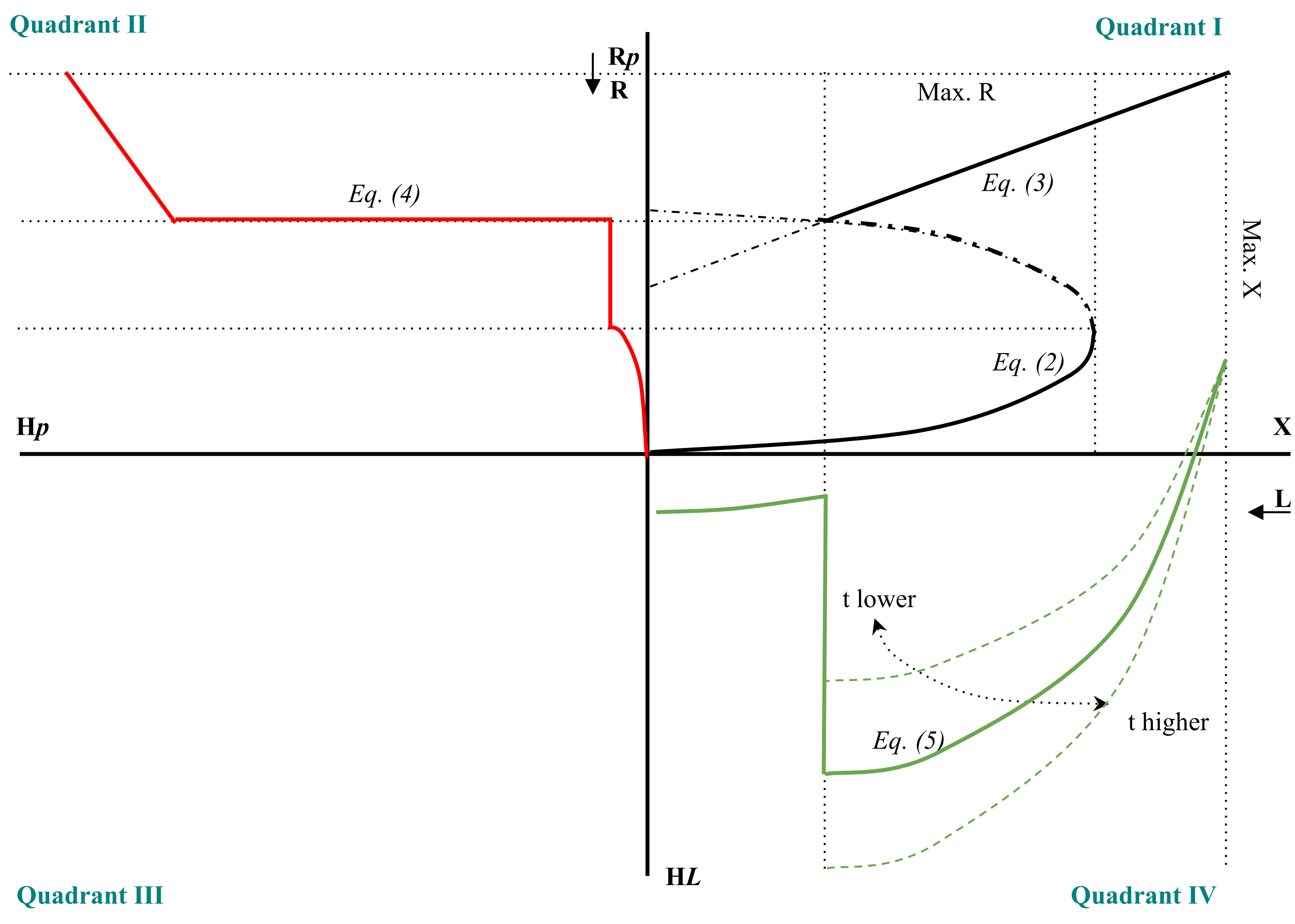

Figure 3: Biosphere richness as a function of solar energy input (black; NE quadrant), net human returns to direct predation (red; NW quadrant), and net human returns to land acquisition for solar generation (green; SE quadrant)

If we want to model at what point the modality of energy harvesting will naturally shift from predation to solar generation, we simply set these two equal to each other such that:

$$H_P = H_L$$

We depict this equation graphically in Figure 4 by permitting investments in predation and solar land use to be fungible (plotted on the x-axis). The results show, as we anticipated, that the ecological breakpoint will be reached more quickly under a predatory model of energy harvesting than it will under a land appropriation model. However, if the technological coefficient is too low or the overhead costs of deploying solar technology too high relative to the ecological breakpoint, the net marginal benefits of a solar economy may not exceed those of a predatory economy before the ecological breakpoint. But even that eventuality is unfeasible, as a post-collapse land-appropriation model of the economy is also greatly impoverished. In effect, there may be a discontinuity between models—a transition from a predatory to a competitive (land-based solar) economy may require coordinated substitution, and at substantial initial cost. Such a transition may not be effected automatically in the classic conception of a free market economy due to the fact that the solar economy may still yield marginal returns below those of the predatory economy until *after* the predatory economy collapses.

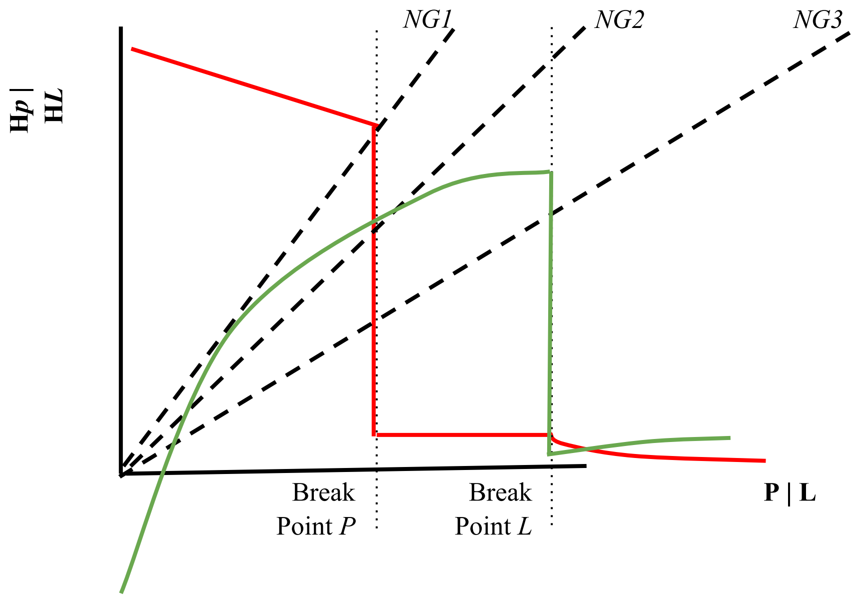

Figure 4: Net human returns to direct predation (red) and land acquisition for solar generation (green), with three possible “no growth” equilibrium lines

We may also posit the existence of a line describing a “no growth” scenario, passing through the origin at a 45° angle (if both X and Y axes are using equivalent units). The addition of this line (with three of its possible locations illustrated in Figure 4 by the three bold dashed lines, *NG1*, *NG2*, and *NG3*) implies a single pooling equilibrium for the appropriative model, and implies that there is a good chance (for any *NG* lower than *NG1*) that the equilibrium will actually occur during or after ecological collapse, and too late to recover. By contrast, there may or may not exist a pooling equilibrium in the case of the “competition” scenario of Earth-based solar harvesting. *NG1* implies no possible equilibrium at all; *NG2* implies a pooling equilibrium occurring before ecological collapse; and *NG3* implies a pooling equilibrium after the economy’s overshoot of collapse break point *L*. Therefore, the terrestrial solar harvesting model is theoretically indeterminate.

Extensions and conclusions

This model's implications for energy policy are clear enough: theoretically, substantial government investment in Earth-based solar generation is required to effect a planetary energy transition to avert ecological collapse. That is, the model demonstrates a reason for skepticism that this transition will happen automatically as a function of substitution by individual economic actors prior to ecological collapse; rather, it may require top-down coercive and/or incentive measures applied by government. For instance, incentives might include direct subsidies covering the overhead costs of electrification—some energy economists have posited that energy transition will be feasible only if consumer electricity fees are reduced to their marginal costs[25]. They might also include the removal of current direct subsidies for fossil fuels, as well as the removal of indirect environmental subsidies for the sector—the combined total of which summed to around USD 650bn per year in 2021 in the United States alone[26]. The removal of indirect subsidies would likely take the form of Pigouvian taxes levied transnationally on CO2 and other greenhouse gas emissions associated with fossil energy. In short, an energy transition may require planning on a planetary scale. Moreover, such a wholesale transition, involving massive, coordinated investments at a global scale, will be costly for the economy as a whole in the short-term, but beneficial in the long-term. Managing social and political expectations in this scenario is of the utmost importance.

If the model's simplicity is its strength, it is also a weakness. A simple dynamism was introduced in the evolution of environmental systems as a function of solar radiation, allowing discontinuities to develop and diverge from each other. But there is no such dynamism modeling the human economy. Elements such as the overhead costs of renewable technologies remain exogenous and static. However, to the extent that humans are able to analyze environmental changes and anticipate collapse, we might well expect that the opportunity costs of remaining in a predatory energy model would rise. This might have the effect of rounding the sharp downward of the red line in Figure 4, potentially even allowing it to cross the green line before Break Point P. Likewise, the technological constant, t, as well as the returns to scale, γ , from Equation 5 are also both static in the model, but might well not be in life: more investments might drive either one higher, again making it more likely that the green line overtakes the red before Break Point P. Either way, such an intersection would represent a successful "automatic" energy transition. However, since the Earth is currently the sum total of all viable future investment strategies, it would seem prudent not to assume that such happy changes will occur in the nick of time, but rather build in a healthy insurance buffer.

The model is overly simplistic in another way. Ecological scientists have determined that we have already entered the sixth mass extinction event in the roughly 3.8 billion year history of life on this planet.[27] It might therefore be argued that we no longer may aspire to avert an ecological collapse—it is happening. It bears keeping in mind, however, that the parsimony of the model presented above may yield certain insights into nonlinearities of energy transitions, but vastly over-simplifies the ecological dynamics of resilience and collapse, which operate in complexly layered and overlapping ways across varied biomes and habitats. Climatological authorities such as Climate Action Tracker stress the non-binary nature of ecological collapse due to climate change. They observe that the Glasgow COP26 policy goals of getting to worldwide net zero carbon emissions by 2050 are very hypothetical, and that current policies are likely to allow the planet to warm past the benchmark of 1.5C over pre-industrial average temperatures (landing somewhere closer to 2.4C). Climate Action Tracker breaks the effects of climate change on the natural environment into four categories of increasingly catastrophic impact based on global average temperature increases: 0–1.5C, 1.5C–2.0C, 2.0–3.0C, and 3.0–4.0C.[28]

This article's model, as indicated in the introduction, may also be extended to include space-based solar power (SBSP) harvesting—a strategy rather blithely termed "mutualism," but for a reason. Apart from land for human habitation, natural resource extraction, and large energy transmission receivers, SBSP would not require further terrestrial extensification for solar harvesting, and might therefore be expected to yield land back to natural systems. We might envision this model as permitting Figure 3's x-axis to extend to allow the H_L function more "runway" for takeoff, and adjusting the slope ($\triangle H_L/\triangle L$) more steeply for technical reasons, including constant solar exposure

25 Heal (2022).
26 Bertrand (2021).
27 Barnosky *et al*. (2011); (Kolbert, 2015).
28 Climate Action Tracker (2021).

(there is no nighttime in space), and the absence of atmospheric interference with solar radiation. However, the present state of orbital launching technology would also make the overhead costs extremely high, further lowering the y-intercept for H_L and likely entirely negating the upside, at least for now. But in the long term, SBSP might more closely resemble "mutualism" between the human and natural environment to the extent that the resources for energy harvesting technology may be mined or captured in space and harvested energy is invested in environmental restoration and re-wilding.

Finally, while many technologies are deemed to be more or less "sustainable," this model suggests that none are necessarily in the absence of government interventions involving some combination of incentives and coercion. The "competition" approach of Earth-based solar harvesting may be truly sustainable, finding an equilibrium position within the ecological limits of the ecosystem. But it might also *not* be, and we lack an empirical test of which it is. Erring on the side of prudence then, guaranteed sustainable economic performance in any model described above requires that governments or other institutions restrain resource exploitation. In some ways, this should come as no surprise. Hardin's famous "Tragedy of the Commons" made a similar claim over half a century ago. [29] Douglas North defines institutions as the formal and informal "humanly devised constraints that structure human interaction",[30] and economic performance is now widely acknowledged to be enabled and conditioned by them in all of their manifestations[31]: the firm;[32] common pool resource (CPR) management institutions and community-driven regulation;[33] the rule of law;[34] state regulation of industry and natural resource exploitation systems;[35] and global trade infrastructure.[36] Such humanly devised constraints usually promote economic growth by eliminating predation among those recognized as valid economic actors (for example, the wide-ranging debate on the relationship between slavery abolition and economic growth[37]).

In effect, then, this model suggests that progress toward sustainability necessitates recognizing some traditionally non-economic (and non-human) actors as exempt from human predation. The art and practice of peacebuilding and conflict transformation has developed a long tradition of breaking down dichotomous frames: "us" and "them," "in" and "out," "native" and "foreign." Transitions toward true sustainability will likely involve a kind of ecological peacebuilding—abandoning the human–nonhuman dichotomy in favor of a greater inclusivity based on a deepening appreciation of inter-species interdependence.[38]

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29 Hardin (1968).
30 North (2003).
31 (Acemoglu, Johnson, and Robinson, 2005); Rodrik (2000).
32 As articulated early on by Veblen (1904).
33 O'Rourke (2002); Ostrom (1990).
34 Haggard, MacIntyre, and Tiede (2008); (Kennedy, 2006).
35 (Acemoglu, Johnson, and Robinson, 2001); Evans (1995); Snyder and Bhavnani (2005).
36 Roy (2019).
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38 Haraway (2016).

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Conflict escalation during neutral and biased humanitarian military interventions

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Abstract

This article considers the effects of humanitarian military interventions (HMIs) on conflict in the countries in which they have been used. Theoretically, neutral HMIs, in which interveners target all violent actors, are expected to have a pacifying effect on conflict intensity by increasing the cost of violence for all parties—while biased HMIs can escalate conflict intensity, by reducing the cost of violence and so encouraging the supported parties to become more violent. The empirical results show that neutral HMIs do seem to lead to lower conflict intensity in the targeted countries, relative to other conflict-affected countries. Anti-rebels HMIs are observed to escalate conflict both in the short and the long run, while the evidence for anti-government HMIs is mixed.

Humanitarian military interventions (HMIs) have been argued by both politicians and scholars to be an effective political strategy to end violent conflicts, establish peace, and protect civilians' lives.[1] The case for intervention is made by highlighting several infamous episodes of mass atrocities in countries such as Bosnia, Rwanda, Kosovo, Afghanistan, and Libya. They argue that these conflicts would not have been resolved or would have worsened without determined military action. The deployment of military force is argued to have acted as a deterrent and have compelled perpetrators of atrocities to opt for a negotiated solution to the conflict, or at the very least, to reduce conflict intensity from its pre-intervention level.[2] In contrast, anti-interventionists have argued that HMIs are counterproductive and can escalate violent conflicts. They can lead to nationalist backlashes against foreign occupation and insurmountable logistical challenges in foreign lands that can drag foreign militaries into "endless wars".[3]

Between these two there is an approach that distinguishes neutral interventions from biased interventions. Both powerful and weak actors involved in the conflict are modeled as political actors, with the payoff from engaging in violent conflict assumed to depend on the cost of violence and the likelihood of three outcomes which are victory, defeat, and settlement. The success of military interventions depends on lowering the expected payoff and likelihood of victory of the belligerents.[4] Biased interventions can fuel conflict by decreasing the cost of violence and increasing the probability of victory for the supported party, leading to "perverse" incentives for the supported party to escalate

1 Former British Prime Minister Tony Blair, a passionate advocate for humanitarian military interventions, said in his speech delivered at Sedgefield (U.K.) in 2004 "The best defense of our security lies in the spread of our values". Alluding to the kind of values which he thought must be promoted and which, in his opinion, should lead to political stability and economic prosperity, he further added that "citizens who are free, well-educated and prosperous tend to be responsible, to feel solidarity with a society in which they have a stake; so do nations that are free, democratic and benefiting from economic progress, tend to be stable and solid partners in the advance of humankind." Articulating his defense of military interventions on humanitarian grounds he observed "And we do not accept in a community that others have a right to oppress and brutalize their people. We value the freedom and dignity of the human race and each individual in it." See full text of the speech at https://www.theguardian.com/politics/2004/mar/05/iraq.iraq .
2 Smith (1994); Perriello (2012).
3 Reisman (2004); Snow (2015).
4 Bove (2011).

Humanitarian military interventions (HMIs) are launched on the pretext of pacifying violent conflicts. However, HMIs in which intervener(s) act discriminately against the conflict actors (whether rebels or government) are likely to be counter-productive and escalate conflict. Biased interventions can fuel conflict by decreasing the cost of violence and increasing the probability of victory for the supported party—thereby invigorating it to escalate its violence. Neutral interventions, however, appear effective in reducing violence.

the fighting.[5] In contrast, neutral interventions where military action is taken against all belligerents can increase the cost of violence for all parties, and so have a pacifying effect. This perspective mainly accounts for how the intervener's political commitments (neutral or biased), manifested in military action, shape incentives for conflict parties to continue engaging in violence. In the case of other types of intervention, for instance, diplomatic interventions, these same commitments might lead to different outcomes. For example, it has been argued that mediation by a highly biased power can enforce conflict resolution by revealing a credible threat of military intervention in case the negotiations fail.[6]

This article empirically analyzes the effects of neutral and biased HMIs on conflict escalation. It follows Gromes and Dembinski's[7] definition of humanitarian military interventions as military intervention in which a state or group of states threaten or deploy military force to save individuals, from national backgrounds other than of their own, from violent emergencies. It also employs their newly digitized database—which includes both unilateral and multilateral interventions. Acknowledging that no HMI can be exclusive of other non-humanitarian objectives, they identify a humanitarian motive by "asking whether decision-makers expressly claim the objective of stopping or reducing violence within the target country." [8]

Further, this article tests the hypotheses that neutral HMIs have a pacifying effect on conflict and that biased HMIs (anti-government/anti-rebels) aggravate the conflict (using a large panel database covering 1946–2019). The database covers all episodes of HMIs during the post-second world war period which were launched to address ongoing violent emergencies[9]. Unlike previous databases on military interventions, it excludes cases of humanitarian relief efforts[10], strictly focuses on humanitarian interventions that are launched to stop atrocities, and also covers a longer period than existing studies.[11]

There is mixed empirical evidence on the effects of military interventions on conflict. While some studies have observed biased military interventions lead to negative effects on civilian security[12] (the likelihood of civil war termination[13] and extrajudicial killings[14]), others have found neutral interventions ineffective in stopping politicides, genocides, and mass atrocities.[15] One of the drawbacks that the existing literature suffers from, and which may to an extent explain contradictory results, is that it aggregates different types of military interventions which may have different effects on conflict. While some studies do distinguish between different types of military interventions based

5 For instance, the level of atrocities committed by the national army of the Democratic Republic of Congo increased after the United Nation's Force Intervention Brigade (FIB) intervened in the country and allied with the army to fight against armed militias (United Nations Security Council, 2017)
6 Favretto (2009).
7 Gromes and Dembinski (2019)
8 See the codebook of Gromes and Dembinski's (2019) Humanitarian military interventions dataset, p. 7. Link: http://www.humanitarian-military-interventions.com/wp-content/uploads/2019/08/PRIF-data-set-HMI-codebook-v1-14.pdf .
9 Violent emergency is defined as an armed conflict between the government and non-state actors or one-sided violence which result in 25 or more deaths in a year time.
10 These include the deployment of military force in foreign territories to assist in relief efforts following natural disasters.
11 For instance, Kisangani and Pickering, (2008) and Sullivan and Koch, (2009) databases end in 2005 and 2003 respectively
12 Wood, Kathman and Gent (2012).
13 Kim (2012); Sawyer, Cunningham and Reed (2015).
14 Peksen (2012).
15 Krain (2005); Conley and Hazlett (2020)

on motives (humanitarian/non-humanitarian) and political position (biased/neutral) of the intervener—but even that does not sufficiently cleanse the noise from the data. For instance, the majority of the existing literature uses older military intervention databases[16] which employ a very wide definition of humanitarian military interventions (e.g., including evacuation missions along with full blown military assaults). The older databases also suffer from temporal limitations and end in the mid-2000s. To address these, this article provides a refined analysis of the HMIs which involves military actions to resolve ongoing violent emergencies. Benefiting from the Gromes and Dembinski's novel database, it also covers a larger timespan of 1945–2019.

Table 1: Types of humanitarian military interventions 1945–2019

Type	*Quantity*	*Period (years)*	*Years per intervention*
Neutral	20	75	3.75
Anti-Rebels	12	59	4.91
Anti-Government	9	19	2.1

Source: Gromes and Dembinski (2019)

There is some relevant literature that lends support to the view that neutral HMIs lead to conflict resolution. Peacekeeping missions are closely related to neutral HMIs[17] and several studies have found that peacekeeping missions lead to a reduction in the level of atrocities.[18]

Conflict and humanitarian military interventions 1945–2019

Figure 1 shows that of the 41 episodes of HMI in the database, only 6 were experienced in the period of 1945–1990. These are: The United Nations' intervention in D R Congo (1960–64), India's intervention in the then East Pakistan (1971), the Arab League's intervention in Lebanon (1976–79), Tanzania's intervention in Uganda (1979), the United States' intervention in Lebanon (1982–84), and India's intervention in Sri Lanka (1987–90). The remaining 35 HMIs were in the era following the break-up of the Soviet Union. As Table 1 shows, in 20 cases, the interveners deployed military forces to counter violence from all parties in the conflict (here termed "neutral HMIs"). In the remaining 21 HMIs, the main targets were either the government forces or the rebel groups (here termed "biased HMIs").[19] The longest duration HMIs were those in which the primary targets were non-state rebellious groups, which lasted, on average, around 5 years.

The data source used for conflict intensity is the Uppsala Conflict Database Program (UCDP) Conflict Termination Database Version 1.0[20] and is examined over the period of the HMI and 7 years before and after. Conflict intensity is an ordinal variable measured on a three points scale of 0,1 and 2 which represent less than 25, between 25–999, and 1000 or above battle-related deaths a year. As Figure 2 shows, before the interventions were underway, targeted countries were already experiencing excess conflict intensity, defined as the difference between their average conflict intensity and the global (horizontal line). Then, when biased HMIs occurred (year 0) average conflict intensities increased sharply and reached their maximum. While it is possible that these increases were independent of biased HMIs and that HMIs were launched in response, it is also possible that biased HMIs were responsible for worsening conflict intensity. It is not possible to disentangle cause and effect from these trends, but average conflict

16 Kisangani and Pickering (2008); Sullivan and Koch (2009)
17 According to the United Nations three key principles underline peacekeeping missions 1) consent of the parties 2) neutrality and 3) use of force only in defense of forces deployed and the mandate. Hence, the element of neutrality is common to both peacekeeping missions and neutral HMIs. For more see information on peacekeeping see the United Nations' peacekeeping webpage at https://peacekeeping.un.org/en/what-is-peacekeeping (last accessed 16th of September 2022)
18 Hegre, Hultman, and Nygård (2018); Bara and Hultman (2020)
19 Gromes and Dembinski (2019) determine the partiality of an intervention by focusing on the political strategy of the intervener. For instance, they examine whether the intervener attempts to prevent the defeat of any party or takes selective action while enforcing ceasefire or peace agreement.
20 Kreutz (2010).

intensities remained high during the years when HMIs were ongoing. Except for the first year following the anti-government HMIs, the difference from the global average conflict intensity remained relatively large during the period post biased HMIs, widening after 2 years. Interestingly, the neutral HMIs saw a reduction in average conflict intensity from the pre-intervention year. For almost the whole post-intervention period, this reduction was to a level that was lower than both the global average in some years and also below that of conflict-affected countries[21].

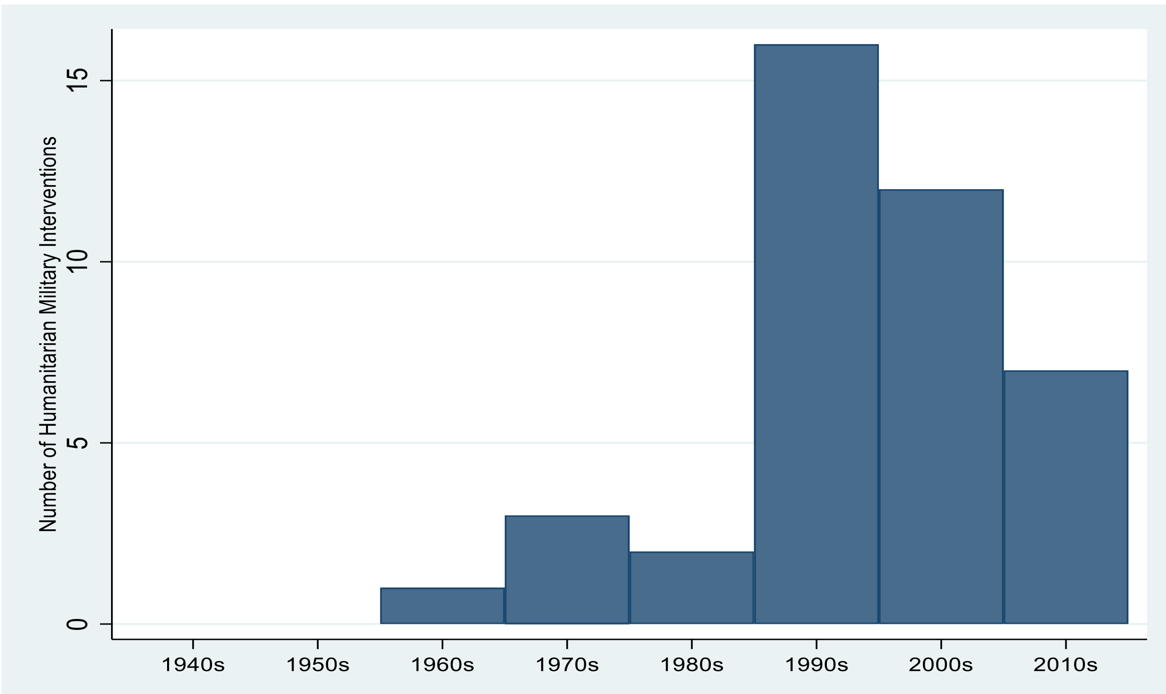

Figure 1: Humanitarian military interventions 1945-2019
Source: Gromes and Dembinski (2019).

While the trends in Figure 2 are insightful, the conflict intensity data restricts the analysis to an annual basis, but it is possible conflict escalation and HMIs occurred at different times during the year. There are 15 cases of HMIs—of which 6 are neutral, 7 anti-government, and 1 anti-rebel—that have starting and ending dates falling within a single calendar year.

Using battle related fatalities data, which is available at a disaggregated level, allows a more detailed analysis. HMIs are launched on the pretext of addressing violent emergencies, hence average daily battle-related deaths should fall from their pre-intervention levels. The main data source for battle-related deaths is the UCDP Georeferenced Database which only starts in 1989. It also does not provide data for ongoing HMIs, so these were calculated and added. The total sample consists of 33 HMIs—16 of which are neutral, 7 anti-government, and 10 anti-rebels. The data for the neutral HMIs is presented in Table 2 and shows that in 14 out of the 16 neutral HMIs the daily average battle-related deaths fell from their pre-intervention levels. Only in cases of the Central African Republic (2013–

21 This comprises those countries which experienced at least one episode of conflict-defined as 25 or more battle-related deaths in a calendar year during the 1945-2019 period.

ongoing) and South Sudan (2011–ongoing) did they increase from the pre-intervention values. These trends are broadly in line with the annual level trends in conflict intensity in Figure 2.

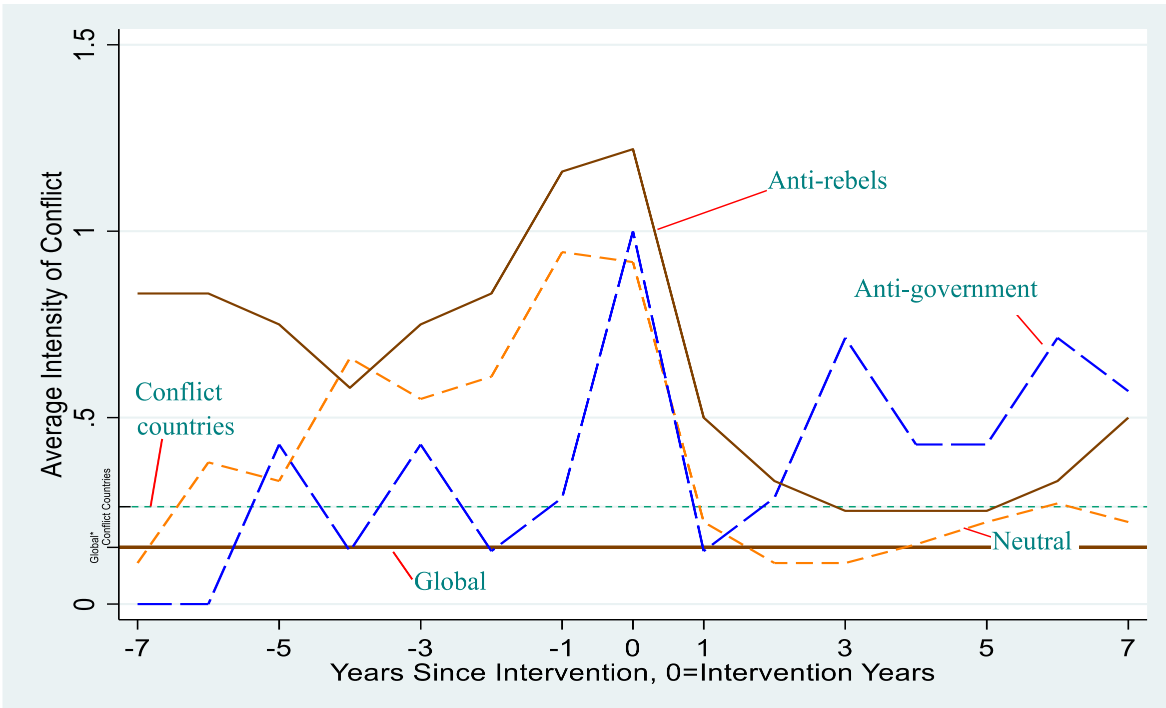

Figure 2: Average conflict intensity and humanitarian military interventions
Source: Gromes and Dembinski (2019).

In the 7 episodes of anti-government HMIs for which data is available, Table 3 shows average daily battle-related deaths increased in only 2 cases from their pre-intervention levels. While not in line with Figure 2, caution is needed as the sample size is so small. Nevertheless, since most of the against government HMIs ended within a calendar year, it is possible that conflicts intensified before the launch of these interventions and were followed by de-escalation once the military action was underway. However, in 3 out of 7 cases of anti-government HMIs, new violent emergencies started within the 5 years of the end of interventions.

On the other hand, the findings for anti-rebels HMIs reported in Table 4 are mixed. In 5 out of 10 cases of anti-rebels HMIs, average daily battle-related deaths increased from their pre-intervention levels whereas in the remaining half they decreased.

Overall, the data suggest that there is some relief in conflict intensity as a result of neutral and anti-government HMIs, but that conflicts escalate when anti-rebels HMIs are ongoing. In the few cases for which data is available, conflicts do also seem to escalate in the post anti-government HMIs period. While these trends are insightful, the effects of HMIs on conflict intensity cannot be isolated without controlling for other potential conflict-causing factors in a multivariate setting and including conflict affected countries that did not experience HMIs.

Table 2: Average daily battle-related deaths during neutral HMIs

Interventions	*Pre Intervention Period*	*Intervention Period*	*Change*
Bosnia and Herzegovina 1993–1995	25.21	20.05	↓
Burundi 2001–2008	3.84	1.82	↓
Central African Republic 2013–ongoing	0.17	4.51	↑
Chad 2008–2010	1.89	1.38	↓
Côte d'Ivoire 2002–2005	95	1.59	↓
DR Congo 2000–2013	20.55	5.73	↓
DR Congo 2003	2.85	0.06	↓
East Timor 1999	28.12	1.22	↓
Georgia (Abkhazia) 1992–1993	NA	4.43	NA
Haiti 2004–2005	5.21	0.37	↓
Rwanda 1994	5497.91	725.95	↓
Sierra Leone 1999–2000	6.43	1.68	↓
Solomon Islands 2003	0.1	0	↓
Somalia 1992–1995	7.86	0.9	↓
South Sudan 2011–ongoing	2.04	3.97	↑
Sudan (Darfur) 2007	8.48	4.59	↓

Source: Gromes and Dembinski (2019), Sundberg and Melander (2013)

Table 3: Average daily battle-related deaths during anti-government HMIs

Interventions	*Pre Intervention Period*	*Intervention Period*	*Change*
Côte d'Ivoire 2011	3.18	1.67	↑
Haiti 1994	0.61	0.27	↓
Iraq (Kurds) 1991–1997	47.88	2.18	↑
Iraq (South) 1992–1996	1.49	0.71	↓
Libya 2011	12.06	7.83	↓
Moldova 1992	1.76	6.23	↑
Yugoslavia (Kosovo) 1999	4.31	25.19	↑

Source: Gromes and Dembinski (2019), Sundberg and Melander (2013)

Table 4: Average daily battle-related deaths during anti-rebels HMIs

Interventions	*Pre Intervention Period*	*Intervention Period*	*Change*
Afghanistan 2003–2014	15.13	16.91	↑
Bosnia and Herzegovina 1995	21.52	1.63	↓
DR Congo 2013–ongoing	5.02	7.25	↑
Iraq 2014–ongoing	122.31	24.27	↓
Liberia 1990–1996	14.8	5.79	↓
Mali 2013–ongoing	0.97	1.81	↑
Sierra Leone 1997–1999	4.02	13.52	↑
Sierra Leone 2000–2001	6	0.83	↓
Somalia 2007–ongoing	3.44	5.47	↑
Tajikistan 1993–1996	9.29	3.11	↓

Source: Gromes and Dembinski (2019), Sundberg and Melander (2013)

Multivariate analysis of conflict intensity and humanitarian military interventions

Panel data on 96 countries that experienced at least one conflict episode (more than 25 battle-related deaths in a calendar year) during the 1946–2019 period was constructed, and a conflict dependent variable created. This was an ordinal conflict intensity variable, 0 (below 25), 1 (between 25–999), and 2 (1000 or above) battle-related deaths where levels 1 and 2 are referred to as minor conflicts and war, so an ordered probit regression method was used. Fixed effect regression analysis was used as a robustness check. The main explanatory variables are neutral, anti-rebels, and anti-government HMIs, introducing up to 3 lags for each of these variables.

Several other control variables are also included in the model to capture conflict history, and economic and political characteristics which have been observed in existing models to be closely related to conflict dynamics. [22] These include: Lagged conflict intensity, a dummy for new conflict[23], GDP per capita growth rate, life expectancy, military expenditure/ GDP, logged total population[24], an index for material capability[25], ethnic fractionalization[26], and a human rights observance score.[27]

The results are presented in Table 5, with Model 5.1 showing that the contemporaneous effect of anti-rebels HMIs

22 Esteban and Ray (2008); Hegre, Hultman, and Nygård (2018); Sawyer, Cunningham and Reed (2015).
23 Data sources: Gleditsch, *et al*. (2002) ; Pettersson, *et al*. (2019).
24 Data source for GDP per capita growth rate, life expectancy, total and urban populations: World Development Indicators database of the World Bank (2021).
25 Material capability is a composite index of six variables which include military personnel, military expenditures, iron and steel production, primary energy consumption, total and urban population. The index is constructed by first dividing each state's share into these six components with the total of these components in the whole system. Then for each state, the average of all relative shares is computed which gives the index of material capability and which has a score between 0 and 1. The data for material capability is taken from the Correlates of War Project (Singer, Bremer, and Stuckey, 1972: Version 6.0).
26 Ethnic fractionalization measures the probability of randomly selecting two individuals not to be from the same ethnic group. Data source: Drazanova (2019).
27 Human rights observance is measured on a scale where the global average is set at 0. The higher number reflects better human rights observance. Data source: Fariss(2019).

on conflict intensity is positive and statistically significant, having a p-value of less than 5 percent. This result is consistent in Model 5.2, which is estimated using a fixed effect estimator. The coefficient for anti-government HMIs is also positive but statistically insignificant and the coefficient for neutral HMI has a negative sign (and is also not significant). Models 5.3 and 5.4 show that for the lagged variables the coefficients for both neutral and anti-government HMIs are negative and significant—however anti-rebel HMIs has a positive sign (but it is statistically significant only in Model 5.4). In models 5.5 and 5.6, which include two lags for intervention variables, the coefficient for neutral and anti-government HMIs are still negative and statistically significant whereas the coefficient for anti-rebels HMIs is positive (and statistically significant). Finally, in models 5.7 and 5.8, 3 lags are introduced with the results indicating a large positive effect of anti-government HMIs on conflict intensity—the effect of anti-rebels HMIs is still positive and statistically significant.

So, there is consistent evidence that anti-rebels HMIs escalate conflict intensity, while the evidence for anti-government HMIs is mixed. While these interventions negatively correlate with conflict intensity with lags of 1 and 2 years, the impact becomes positive after a lag of 3 years. The results also show that neutral HMIs lower conflict intensity in the long run.

The average marginal effects from the contemporaneous model in Table 6 show that country-years that experience anti-rebels HMIs are about 6.9 percent more likely to experience minor conflict and 4.9 percent more likely to experience war, as compared with country-years that do not experience such interventions. The marginal effects for anti-rebels HMIs in the long-run models are in the range of 6.1–4.8 percent for minor conflict and 4.3–3.4 percent for war. Hence the likelihoods of experiencing minor conflict and war significantly increase in countries that experience anti-rebels HMIs, compared with conflict-affected countries that do not.

The average marginal effects for neutral HMIs from long-run models show that country-years which experience these interventions are approximately 2.8–3.8 percent less likely to experience minor conflicts and 2.7–2.0 percent less likely to experience war as compared with the baseline conflict-affected countries with no such interventions.

On the other hand, while anti-government HMIs reduce the likelihoods of minor conflict and war by a significantly high magnitude (62–43 percent for minor conflict and 44–33 percent for war), the impact turns positive after a lag of three years (41 and 29.7 respectively). In other words, anti-government HMIs seem to lead to a reduction in the level of atrocities with a lag of 1 and 2 years but eventually, the impact turns positive and assumes a magnitude that is substantially larger than that of anti-rebels HMIs after a lag of 3 years. However, it should be noted that the findings for anti-government HMIs might be affected by a small sample size as the data for these HMIs is only available for 19 years as compared with 75 and 59 years for neutral and anti-rebels HMIs.

These results are partially in line with the descriptive trends observed in Figure 2. Anti-rebels HMIs are observed to lead to an increase in conflict intensity in both contemporaneous settings and in the long run as compared with conflict-affected countries which do not experience any such interventions. Conflict intensity increases when the anti-rebels HMIs are ongoing and remain above the global average even in the post-intervention period. While conflict intensity also peaked during anti-government HMIs, there is no evidence to suggest that this is caused by the interventions. However, Figure 2 also showed conflict intensity increasing to a high level 2 to 3 years after the end of these interventions and the results shown in Table 5 for models 5.7–5.8, which include anti-government HMIs variable with a 3 year lag (most of which lasted less than a year), seem to suggest that the anti-government HMIs contributed to these increases.

Table 5: Regression results, dependent variable: Conflict intensity scale from 0 to 2

	Model 5.1	*Model 5.2*	*Model 5.3*	*Model 5.4*	*Model 5.5*	*Model 5.6*	*Model 5.7*	*Model 5.8*
Variables	*Ordered Probit*	*Fixed Effect*	*Ordered Probit*	*Fixed Effect*	*Ordered Probit*	*Fixed Effect*	*Ordered Probit*	*Fixed Effect*
Neutral HMIs	-0.233 (0.41)	-0.035 (0.56)						
Anti-Government HMIs	0.577 (0.45)	0.305 (0.42)						
Anti-Rebels HMIs	0.926** (0.02)	0.432*** (0.00)						
Neutral $HMIs_{t-1}$			-0.515* (0.06)	-0.156** (0.01)				
Anti-Government $HMIs_{t-1}$			-8.40*** (0.00)	-0.882** (0.03)				
Anti-Rebels $HMIs_{t-1}$			0.577 (0.24)	0.289 (0.05)**				
Neutral $HMIs_{t-2}$					-0.382* (0.09)	-0.122** (0.02)		
Anti-Government $HMIs_{t-2}$					-5.83*** (0.00)	-0.321*** (0.00)		
Anti-Rebels $HMIs_{t-2}$					0.824 (0.01)**	0.328*** (0.00)		
Neutral $HMIs_{t-3}$							-0.543 (0.15)	-0.154** (0.02)
Anti-Government $HMIs_{t-3}$							5.58*** (0.00)	0.861*** (0.00)
Anti-Rebels $HMIs_{t-3}$							0.645** (0.07)	0.225 (0.11)
Wald- LR Statistic /Prob > chi2	717.29 (0.00)	5302.29 (0.00)	2105.91 (0.00)	4391.12 (0.00)	3122.46 (0.00)	4823.18 (0.00)	2186.26 (0.00)	75723.04 (0.00)
Observations	3414	3414	3414	3414	3414	3414	3414	3414

Notes: All models include battery of control variables. Ordered probit models also include regional dummies. Parentheses contain p values. *** p< 0.01, ** p<0.05. Robust clustered standard errors estimated in all models. Constant included in all models.

Table 6: Average marginal effects

Model	*Intervention*	*0 (less than 25 battle-related deaths)*	*1 (25-999 battle-related deaths)*	*2 (1000 or above battle-related deaths)*
Model 5.1	Anti-Rebels	-0.118	0.069	0.049
Model 5.3	Neutral	0.065	-0.038	-0.027
	Anti-Gov	1.02	-0.626	-0.446
Model 5.5	Anti-Rebels	-0.105	0.061	0.043
	Neutral	0.048	-0.028	-0.020
	Anti-Gov	0.747	-0.436	-0.310
Model 5.7	Anti-Rebels	-0.082	0.048	0.034
	Anti-Gov	-0.717	0.419	0.297

As far as the neutral HMIs are concerned, there is evidence that suggests a long-run pacifying effect on conflict. It can be observed in Figure 2 that the slope of the curve for neutral HMI is negative starting from 1 year before interventions until 3 years in the post-intervention period. Average conflict intensity remained lower in countries that experienced neutral HMIs as compared with other conflict-affected countries.

As a robustness check for the non-randomization of HMIs, an instrumental variable regression method was used, with instruments generated from the heteroscedasticity in the errors of the endogenous covariate, i.e., humanitarian military intervention variable.[28] The results from IV regression support the findings from the fixed effect models that neutral HMIs lower conflict intensity whereas biased HMIs have the opposite effect.[29]

Some case study evidence

It is beyond the scope of this study to test in detail the underlying mechanism causing the diverging effects of neutral and biased HMIs on conflict intensity. But there does seem to be case study evidence to support the plausibility of the perverse incentive argument that biased interventions encourage the supported parties to escalate the fighting, particularly in case of anti-rebels HMIs. The African Union Mission in Somalia (AMISOM)[30] was formed in 2007 to stop atrocities committed by the Al-Shabab group. This intervention is coded as an anti-rebel and the results in Table 5 would suggest it would escalate violent conflicts. A Human Rights Watch report suggests that the bias demonstrated during the intervention encouraged anti-Shabab forces to escalate the level of violence, describing AMISOM action as turning a blind eye to their allies' "abuses on the ground".[31]

Another relevant case is that of the Force Intervention Brigade (FIB) of the United Nations Mission in the Democratic Republic of Congo. The FIB was established in 2013 to counter four armed groups (out of a total of 70 groups operating in the country): The Front for the Patriotic Resistance in Ituri (FRPI), the Lord's Resistance Army

28 Lewbel's (2012) method is used to generate instruments from the heteroscedastic errors of the humanitarian military intervention variable. Note that HMI is a binary variable, so its errors are heteroscedastic by construction.
29 Interested readers can find detail on Lewbel's (2012) methodology and the results from instrumental variable regression in Saeed (2022).
30 AMISOM is composed of troops from African countries such as Kenya, Uganda, Burundi, Djibouti and Ethiopia.
31 Human Rights Watch, (2010: 5).

(LRA), the Allied Democratic Forces (ADF), and the Democratic Forces for the Liberation of Rwanda (FDLR).[32] The mission in fact worked in collaboration with the Congolese army (FADRC), which was accused in the United Nations' own confidential report "as a party to numerous violations" and that "Government security forces, particularly FARDC, remain a significant source of sexual violence, notably against minors."[33] Further accusations were made in the United Nations' 2017 report which noted that the Congolese army was responsible for 64 percent of documented violations of human rights, including extrajudicial killings of at least 480 civilians in 2016.[34] It appears that the intervention indirectly encouraged the Congolese army, which has a dismal human rights record, to increase the scale of atrocities against civilians and its opponents.

The positive long-run effect of anti-government HMIs on conflict intensity is likely to result from long-run instability caused by the weakening of the regimes which these interventions, mostly, lead to. While such interventions can stop oppressive regimes from perpetrating atrocities in the short-run, the level of violence seems to increase again in the long run. The case of Libya is illustrative in this respect. The number of battle-related deaths was approximately 3914 in 2011 after the Gadaffi regime started violently cracking down on the opposition. The number fell in 2012 and 2013 to 378 and 36 respectively and then started increasing again in 2014 to reach some 1455 such deaths.

Conclusion

This article examines the effects of humanitarian military interventions(HMIs) on conflict intensity in the targeted countries. Its key contribution lies in utilizing a novel HMIs database developed by Gromes and Dembinski, which unlike previous databases covers a larger time span of 1945–2019. Also, the focus is on HMIs which were launched to address ongoing violent conflicts. Unlike several previous studies, it excludes cases of humanitarian interventions which did not involve the objective of containing violence, such as evacuation missions, as their inclusion might distort statistical inference on the effectiveness of HMIs in reducing violence.

Humanitarian military interventions (HMIs) are launched on the pretext of pacifying violent conflicts. These interventions involve the deployment of military power which has humanitarian, economic and political consequences both for the targeted countries and the interveners. The findings from this study suggest that HMIs in which intervener(s) act discriminately against the conflict actors are likely to be counter-productive and further escalate conflict intensity. In other words, they may end up worsening conflict situation. On the other hand, if the intervener acts indiscriminately against all perpetrators of violence, the chances of conflict de-escalation are high. While some caution is necessary due to data limitation (e.g., the small sample size for anti-government HMIs), these findings are also supported by insights from several case studies of interventions in Africa (e.g., in the Democratic Republic of Congo since 2013).

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Tracking the SDGs: A methodological note on measuring deaths caused by collective violence

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Abstract

As part of recording the progress toward promoting peaceful societies as envisioned in the Sustainable Development Goal (SDG) 16, it is important to provide accurate estimates of violence-related deaths (SDG 16.1). These estimations face a number of methodological challenges, resulting in rather conservative estimates in the social sciences. In this article, we discuss SDG indicator 16.1.2 on conflict-related deaths, proposing its enlargement to cover different forms of collective violence. Various types of collective violence, their definition, measurement, and methods to combine them without double counting are reviewed. Comparing the Georeferenced Events Dataset (GED) to the Global Terrorism Database (GTD) shows that events of armed conflict and terrorism overlap to a certain degree. Our argument is that merging data from different event databases can provide a more accurate account of collective violence. We augment the GED data on organized armed conflict with data on terrorism—as a result, our estimates of the numbers of collective violence-related deaths are indeed significantly higher than suggested by GED (one of the most widely used databases in the social sciences).

In 2000, the United Nations set out an aspirational agenda, the Millennium Development Goals (MDGs). The goals ranged from reducing poverty and hunger to achieving universal primary education to combating diseases such as HIV/AIDS and malaria. Fifteen years later global poverty had been more than halved and the MDGs were judged to have produced the most successful anti-poverty movement in history (United Nations, 2015). However, across the world, progress had been uneven and many challenges to human development remained. This inspired the new ambitious 2030 Agenda for Sustainable Development, consisting of seventeen Sustainable Development Goals (SDGs). Unlike the MDGs, the SDGs include a target to promote peaceful societies, aiming to reduce all forms of violence and related deaths everywhere (SDG target 16.1). In order to gauge progress, two important indicators are the number of intentional homicides (16.1.1) and conflict-related deaths (16.1.2). In this article we discuss why this distinction results in an undercounting of violent deaths. Further, we make suggestions on how to address this problem by measuring “collective violence” instead of only conflict-related deaths. We start with the observation that conflict-related death figures provided by social scientists tend to be conservative and argue that merging data from different event databases can provide a more accurate account of collective violence related deaths. In the following section, we elaborate on the definition of conflict-related deaths followed by an introduction of commonly used event datasets. Next, recently developed methods of merging these data are discussed and are then applied to present regional and global estimates of collective violence related deaths. The last section provides conclusions and discusses avenues for further research.

Measuring progress on the Sustainable Development Goal 16 currently faces a number of methodological challenges in the estimation of violence related deaths. We propose enlarging on the current estimates to cover different forms of collective violence. Careful merging of data from different established event databases can provide a more accurate account. As a result, estimates of the numbers of collective violence related deaths are significantly higher than suggested by the Georeferenced Events Dataset (GED).

Definitions and data

To track the development and the achievements on SDG 16.1, indicator 16.1.2 aims to capture conflict-related deaths.[1] Here the U.N. understands conflict as the "protracted armed confrontations occurring between governmental armed forces and of one or more armed groups". Two types of conflict-related deaths are considered: First, direct deaths resulting from force; and second, indirect deaths resulting from restricted access to essential goods and services, such as food and medical care, due to the conflict. However, only data sources to measure direct deaths have so far been identified and thus this article will only consider direct deaths. It is important to underline that the U.N. definition of conflict mentioned above excludes violence by an organized group that targets civilians and therefore does not include terrorism. Instead, deaths as a result of terrorist activities are included in SDG 16.1.1, because the U.N. measure of intentional homicides is based on the International Classification of Crime for Statistical Purposes (ICCS).[2] Thus, terrorism deaths should in principle be accounted for if the U.N. homicide statistics are used for tracking progress toward the SDGs. However, the United Nations relies on member states to report homicides, but these reports are difficult to compare, e.g., some countries appear to include deaths from terrorism, while others do not. U.N. homicide numbers are in some cases even lower than the deaths from terrorism, confirming that terrorism deaths are not consistently included in the Criminal Justice data on homicides provided by the member states.[3] It is also of interest to note that, in general, U.N. homicide numbers are lower than the World Health Organization (WHO) estimates of deaths from interpersonal violence, suggesting potential underreporting of deaths from homicide by the U.N. All of this suggests that there are gaps in the definition and data collection efforts by the U.N., which may provide an inaccurate picture of the progress toward the SDGs.

To improve the reporting on the progress of SDG 16 we suggest that SDG 16.1.2 should not exclusively capture the rather restrictive concept of *conflict-related deaths*, but be enlarged to *collective violence*. Even though there is no commonly accepted definition of *collective violence*, we base our following analysis on the definition of the WHO—restricting the concept of *collective violence* to "the instrumental use of violence by people who identify themselves as members of a group against another group or set of individuals, in order to achieve political, economic or social objectives" (WHO, 2002) and, thus, include conflict-related deaths as well as deaths due to terrorism.

In the remainder of this section, we turn to social science data projects that define and collect data on the different forms of collective violence in a systematic manner. We will discuss the available data on armed conflicts between states, within states, between groups and on organized groups that target civilians, including terrorism.

The Uppsala Conflict Data Program (UCDP) provides detailed information on organized armed conflict. UCDP is a large ongoing data collection effort that has become the most commonly used global dataset for research in the social sciences. Within UCDP the Georeferenced Event Dataset (GED) provides detailed information that is also easy to merge with other data. Here an event is defined as "An incident where armed force was used by an organized actor against another organized actor, or against civilians, resulting in at least 1 direct death at a specific location and a

1 https://unstats.un.org/sdgs/metadata/?Text=&Goal=16&Target= accessed 25 May 2022.

2 https://www.unodc.org/unodc/en/data-and-analysis/statistics/iccs.html accessed 25 May 2022.

3 This issue is also mentioned in the methodological annex of UNODC's Global Study on Homicide (UNODC, 2019).

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specific date" (Högbladh, 2021: 4). When at least one organized actor is the state, UCDP refers to these conflicts as **state-based armed conflicts** (making up the majority of conflicts). Conflicts between armed groups that do not include the state, e.g., conflicts between ethnic or religious groups, are categorized as **non-state conflicts**. When armed groups, including the state, kill civilians this is referred to as **one-sided violence**.[4] More generally armed conflicts are contested incompatibilities, causing a minimum of 25 deaths per year. The main sources of information are global newswire reporting (e.g., Reuters News, Agence France Presse, and Xinhua) but the UCDP team also consults local media as well as reports by intergovernmental and non-governmental organizations. Each conflict is assigned a conflict identifier and the GED records details on each conflict event, including the names of the opposing sides, the location and time of the violent event and a count of how many people were killed. Since the compilation of the death counts from news reports requires some judgement on the reliability of the sources, the GED offers estimates of the highest, lowest, and most reliable ("best") estimates.

The three categories of organized violence, state-based, non-state based and one-sided violence, are exclusive and by design there is no overlap. Thus, adding all of the conflict-related deaths provides information on how many people died as a result of direct violence in organized conflicts during a specific period in a particular region. A comparison with alternative sources suggests that the GED conflict death data are conservative. For the year 2015 the WHO estimates that about 186,400 people died as a result of collective violence WHO (2022). This compares to an estimate of about 147,200 from GED based on their "high" death counts (see Table A3 in the Appendix). Country comparisons also suggest that GED numbers are much lower than the estimates from public health studies. As an example, take the careful study of the armed conflict in South Sudan conducted by a team of epidemiologists at the London School of Hygiene and Tropical Medicine. Checchi *et al*. (2018) estimate that about 190,000 people died as the result of direct violence between 2014 and 2018, compared to only 12,200 according to the GED. These differences between social science and public health estimates are due to variations in definitions as well as collection methods.

Fatality data collected by social scientists, such as UCDP, rely on media reports as major information sources, and it is likely that these data suffer from a downward bias. Even though media-reported information on fatalities is easily accessible in large quantities, it is often not complete. Such databases miss events which are not reported, mostly due to deliberate selection or inaccessibility of information on certain incidents. One of the few studies to systematically investigate this under-reporting bias is Weidmann (2016). He compares detailed military data on violent events with GED entries from Afghanistan and his results clearly indicate that events in areas with poor mobile phone coverage are less likely to be reported by GED. Furthermore, incidents with high numbers of casualties among coalition soldiers in accessible places increased the reporting probability. Thus, statistical analysis aiming to explain collective violence measured by such event datasets may risk biased results if the systematic measurement error is associated with the independent variable. More importantly for our work, merely tracking the progress of SDG 16 based on one of such event databases might lead to biased reporting.

Given these known shortcomings of the UCDP data, should we use public health data to estimate collective violence related deaths? Although the WHO provides global and regional data on deaths due to collective violence, these data are not available by country-year over a longer period. There is also little information on how these estimates are derived as the WHO does not provide the estimation method. Alternatively, one could try and collect country or conflict specific studies that have estimated the number of excess deaths. Although this is an active area of research,[5] there is no agreed upon methodology and in many studies it remains unclear how many of the excess deaths are due to the direct impact of violence and how many died due to indirect factors such as hunger and disease.

4 Pettersson et al. (2021); Sundberg and Melander (2013).
5 For example: Burnham *et al*. (2006); Coghlan *et al*. (2006); Crawford (2015); IPPNW (2015); Obermeyer *et al*. (2008).

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Some of the public health studies have also been criticized for overstating the number of victims.[6] These methodological issues make it impossible to add data from different country studies.

Thus, in contrast to the public health studies, UCDP provides data that have been collected by using the same method across all countries, but we acknowledge that this data collection effort suffers from downward bias. One way to address this shortcoming could be to augment the UCDP data collection effort with information from other global event databases covering death estimates due to collective violence. One such data collection is the Global Terrorism Database (GTD), a widely used database for the study of terrorism. For the purpose of the GTD, terrorism is defined as "the threatened or actual use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation".[7] The violence must be intentional, but if it is exclusively used to pursue financial gain it is excluded from the database. In principle, we should be able to add the deaths due to terrorism to the UCDP numbers of conflict deaths because for an event to be included in the GTD "the action must be outside the context of legitimate warfare activities".[8] In Figure 1 we present the data from the two different data sources (2000–2018), the dotted line shows the number of deaths due to organized violence (GED) and the solid line the number of terrorism deaths (GTD). Until 2011 both counts were relatively low, but then increased until 2014. The increase in organized conflict deaths is due to the war in Syria and the increase in terrorism deaths is driven by the events in Iraq. Moreover, both data series are characterized by a very skewed global distribution of the number of deaths. Five countries, Syria, Iraq, Afghanistan, Nigeria, and Ukraine, account for almost 79 percent of all the GED deaths in 2014. The terrorism numbers are dominated by Iraq, Nigeria, Afghanistan, Syria, and Pakistan—these five countries account for almost 74 percent of all global terrorism deaths. Since 2014 both data series, GED and GTD, have been decreasing. Since these trends are similar, it raises the suspicion that the two data series may not measure entirely separate phenomena.

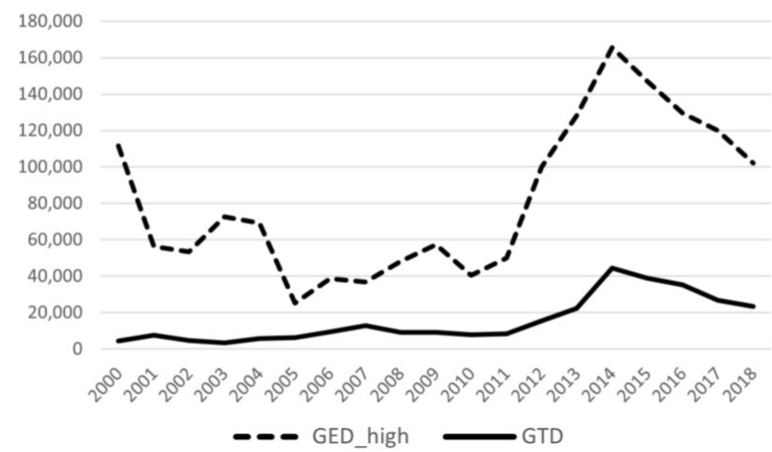

Figure 1: Global number of deaths reported by GED and GTD
Note: For the GED data, the highest reliable estimate of deaths ("high") is used. Zero GED deaths for all countries in "the West" are assumed (for further discussion see the "Methods" section).

Another look at the data also supports the suspicion that the UCDP and the GTD concepts may not be mutually exclusive. All of the top terrorism countries during 2000–2018 are countries that also experienced large-scale armed conflicts during the period: Iraq, Afghanistan, Nigeria, Syria, Pakistan, Somalia, and Yemen. Scholars of civil war have long noted that terrorism is a common tactic in armed conflicts, for example Fortna (2015) suggests that almost one quarter of all insurgency groups use high casualty terrorist tactics in civil war. In this sense, terrorism is not understood as an ideology but as a tactical choice.[9] In contrast, other scholars dispute that terrorism can be defined as a distinct phenomenon as many state and non-state organizations frequently use terrorism alongside other tactics.[10]

6 For further discussion see Johnson *et al*. (2008) and Spagat *et al*. (2009).
7 University of Maryland (2019: 2).
8 University of Maryland (2019: 11).
9 Kis-Katos *et al*. (2014).
10 Tilly (2004).

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Civil war and terrorism are difficult to distinguish, particularly in their early stages. At the start of an armed conflict small groups operate in a clandestine fashion, similar to terrorist cells. Thus, terrorism can also be described as a proto-civil war.[11] These theoretical problems in distinguishing insurgencies from terrorism highlight the difficulties in developing separate measures for deaths resulting from organized conflicts and those from terrorism.[12]

For theoretical and data reasons we cannot improve on the counts of collective violence deaths by simply adding the GTD terrorism deaths, because it would result in overcounting victims. In a theoretical contribution, Sambanis argues that although many insurgents use terrorist tactics in civil war, it may be useful to distinguish terrorism *outside* of civil war from terrorism *within* civil war. He uses the expression "pure terrorism" when he refers to terrorism outside of civil war. Based on this concept, we want to augment the GED estimates by the "pure terrorism" counts. We therefore have to identify the deaths that are listed in the GED as well as in the GTD, but then add terrorism victims that are only listed in the GTD to the GED to obtain an estimate of collective violence deaths. We now turn to the discussion of two different methods that enable us to identify "pure terrorism" and thus avoid double counting.

Methods

Having established that the definitions of organized conflict and terrorism are not mutually exclusive and that some events are included in both the GED and the GTD datasets, we investigate how we can identify the overlap of conflict and terrorism events and the associated deaths. Currently, there are two efforts to systematically compare the two databases. In this section, we describe both approaches and how we can use them for filtering out duplicate entries from conflict and terrorist event databases.

The first method we want to introduce is called the *Matching Event Data by Location, Time, and Type* (MELTT) developed by Donnay *et al*. (2019) for integrating data from different violent event datasets. MELTT's aim is to identify entries in those conflict event datasets that probably refer to exactly the same event through iterative pairwise comparison. The main challenge with this comparison is that the same event may be coded differently depending on the source and differing internal coding practices. Hence, one has to allow for some variation in the measurements.

Donnay *et al*.'s protocol enables researchers to apply this *imperfect matching* technique in a systematic manner. The first parameter users choose is the spatio-temporal window in which entries refer to the same event. Choices can range from same day or preceding/following day(s) and as for location from zero to one or more kilometers apart. This is necessary since event databases do not always record time and place measurements with precision. However, if different entries do refer to the same event, it is likely that they occur within a narrow spatio-temporal window. In a second step, the protocol compares other attributes to distinguish unique from matching events within these windows—such as the type of the events or the actors. If users want to allow for "fuzzier" matches, they can choose from a taxonomy with multiple levels. Unlike the spatio-temporal decisions, the mapping of equivalent categories can be very labor intensive depending on which level of detail the researchers set for their taxonomy. If there are several potential matches, the algorithm decides on the one which is the most similar.

For the present study, Donnay *et al*. kindly provided us with an integrated dataset (the combined data where duplicate events have been filtered out). Specifically, in the case of events co-occurring in both databases, the GTD event was filtered out and the GED event retained in the integrated dataset. Therefore, GTD events remaining in the integrated data can be interpreted as terrorism occurring outside of armed conflict, or "pure terrorism". Data are available for all African countries from 1997 until 2016 and we allowed for 5km spatial and one day temporal "fuzziness". Furthermore, for this integration, the taxonomies created by Donnay *et al*., were on the type of event and the actors involved, as well as the degree of geo-precision. Thus, for all the African countries for the years from 2000

11 Sambanis, (2008).
12 See Hoeffler (2022) for more discussion on the interrelationship between armed conflict and terrorism.

to 2016 we have estimates based on the application of MELTT. To estimate global data for 2000-2018, we extrapolated the information on Africa onto the entire world. From the integrated data, we were able to calculate each of the included country-year's ratios of "pure terrorism" to total GTD deaths and we used these ratios to create estimates for the missing country-years. To obtain estimates for the years 2017–2018 for Africa, we applied each African country's ratio from 2016 to the GTD data for those two years.[13] For the rest of the world, we extrapolated in a rather crude manner. We simply applied the mean ratio of "pure terrorism" to total GTD deaths to all of the countries outside the region that had an ongoing conflict according to the GED.

The second data matching effort is the *Terrorism in Armed Conflict* (TAC) project, which approaches the integration of GED and GTD from a different angle. With the motivation to find out whether rebel organizations use terrorist tactics, Fortna *et al*. (2022) created the TAC database, which matches perpetrators of GTD events with rebel organizations listed by the GED. They do not only consider perfect matches, but they systematically tackle the issue of varying precision regarding the perpetrators of terrorism events. In a large coding effort, they looked in detail at over 9,000 GTD events possibly linked to a UCDP-listed rebel group. It is a unique feature of TAC to allow researchers to include groups that are fractions, umbrellas, or affiliates of the UCDP rebel organizations as well as generic descriptors and unknown links. Accordingly, the TAC project provides different matching levels which users can choose from. For our estimates we included all GTD events where (1) the perpetrators are *connected* in some way with a UCDP rebel group or (2) where generic descriptors are used. For example, the GED lists the Kurdistan Workers' Party (PKK) as one conflict side while events in GTD list groups like Kurdish separatists, Kurdish rebels, and Kurdish militants. We want to match these groups although they are not named as the PKK, since we consider events perpetrated by groups connected to UCDP rebel organizations as part of the armed conflict. In the TAC parlance, we applied level E (Fortna *et al*., 2022: 220) for the classification. However, we do not include events that list "unknown perpetrators" (such as gunmen or individuals, listed as level F) from events that took place in a country during a time period where it could possibly be linked to locally operating rebel organizations. The justification is that we consider that "pure terrorism" can occur even in countries currently in armed conflict.

Using the TAC methodology, the overlap between GED and GTD is defined as events being perpetrated by the same actors. Thus, we removed GTD events perpetrated by a rebel organization listed by the UCDP, or a group connected to one of those, in order to create a measure for "pure terrorism". One of the advantages of TAC is that coverage is global, however it only covers years up to 2013. Therefore, to extrapolate our measure of "pure terrorism" fatalities to more years, we applied each country's ratio of fatalities in GTD which are linked to a rebel organization, from 2013 to all the country-years thereafter.

How good are these methods in recognizing duplicates of violent events and the associated deaths? The main issue with the MELTT methodology arises when the encoding of what actually is the same event differs too much between the two databases. In these cases, the algorithm will not recognize events as duplicates. The TAC methodology, on the other hand, relies on identifying actors and does not rely on exact information on time and place of an event. Using TAC will result in identifying more duplicate events, because MELTT requires information on the time and place of an event. If these are stated imprecisely, MELTT will not recognize these as duplicate events. However, some events may be erroneously identified as duplicates by TAC. If the violence was committed by an affiliated actor listed in the GED, the associated events from GTD will be filtered out even though the *event* might not have been contained in GED. Filtering them out would therefore result in losing this event and its associated fatalities. To summarize, with MELTT one can be more certain that what is filtered out are actually the same events. Using TAC,

[13] To apply Donnay *et al*.'s taxonomies to the latest data on Africa, we would have to check whether they still fit the data and possibly adapt and extend them. While we were unable to do so within the scope of this article, it is worthwhile to tackle this in future research.

it could happen that events committed by a UCDP (related) actor are removed even though they have not been a duplicate but only been contained in the GTD.

Neither the MELTT nor the TAC project provides a matched or integrated dataset with global coverage for the years 2000–2018. MELTT covers only Africa until 2016, whereas TAC covers all countries but only until 2013. Extending estimates of collective violence deaths to achieve global and up-to-date coverage is problematic with the currently available data and taxonomies. So far, we have focused on the countries that experience armed conflicts as well as terrorism. For the many countries that have no ongoing armed conflict it is straightforward to just use the GTD death estimates. For some countries, the use of the GED as a basis may be problematic. Take the example of 9/11. Consistent with public perception, all four events that occurred on this day have been categorized as terrorism by GTD. However, GED classifies the attacks against the World Trade Center as one-sided violence, while the plane crashes in Pennsylvania and Virginia are considered as state-based conflict. The rationale behind this classification is that the GED categorizes events based on the (intended) targets of the attack. Hence, the attacks on the Pentagon and the White House indicates that "the state" was targeted—consequently the GED classifies these events as "state-based armed conflict". Thus, the United States is listed as a conflict country for 2021 in the GED.

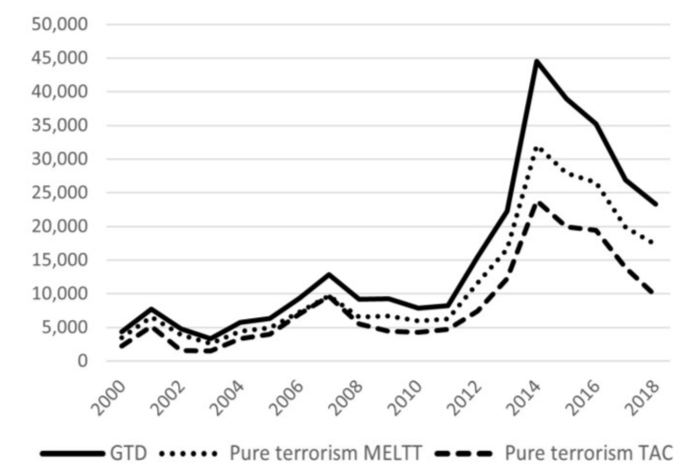

Figure 2: Global estimates of deaths due to "pure terrorism"

Given that some of these categorizations are contested, we decided to assume that no country in "the West" was a conflict country and use the GTD to estimate collective violence for these countries. Apart from fitting in with the common understanding of the type of collective violence in "the West", it has the added advantage that the GTD lists many more events. Since there is no minimum death threshold for events to be listed in the GTD the death toll in "the West" is higher than in GED and addresses somewhat the downward bias in the GED data.

To summarize, for countries with no organized conflicts we use the GTD to estimate deaths from collective violence. For all countries in "the West", we assumed that they were not experiencing organized conflict and use the GTD to estimate deaths from collective violence. For all other countries, i.e., those that experienced organized conflict as well as terrorism, we apply information from TAC and MELTT to estimate conflict-related deaths and "pure terrorism". The sum of conflict-related deaths and "pure terrorism" can be interpreted as a measure of deaths resulting from collective violence. Our current estimates are quite crude—to apply these two methods in deriving global estimates for 2000–2018, we either must assume that the world is like Africa (because MELTT only covers Africa) or that the world is still like it was in 2013 (since TAC only covers 2000–2013).

Estimates

Applying the two estimation methods, MELTT and TAC, we start our analysis by deriving two estimates of "pure terrorism" (terrorism outside of armed conflict). Figure 2 provides three time series: GTD; "pure terrorism" from our application of MELTT; and a "pure terrorism" estimate based on TAC. By construction our "pure terrorism" estimates are always lower than GTD death counts, and the MELTT estimates of "pure terrorism" are always between the GTD and TAC estimates. In the early 2000s it is difficult to distinguish the lines, i.e., with our methods we identify only very few events that are in the GED as well as in the GTD databases. This changes over time and around 2011 there

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is a considerable difference between GTD and the "pure terrorism" estimates. All the terrorism estimates peak in 2014 and for this year the difference is very pronounced. Our global MELTT estimate is about 28 percent lower than the GTD count. The country with the largest difference is Nigeria, as about 45 percent of all Nigerian deaths in the GTD are also in the GED. The total difference is almost 3,500 deaths. The global TAC estimate is even lower. It is about 46 percent lower than the GTD counts, again there is a particularly large discrepancy for Nigeria, where about 79 percent of the deaths are included in the GED and the GTD.[14]

Table 1 presents an overview of the data used and our estimates of deaths due to "pure terrorism" and collective violence. In column 1 we present the sum of all deaths listed in the GED for 2000–2018 by region (see Appendix tables A1 and A2 for regional classification). The last row provides the global sum. According to the GED over 1.5 million people died as a result of direct violence in organized conflicts during this period. This is equivalent to almost the number of inhabitants of Philadelphia or the entire population of Equatorial Guinea. The Middle East and North Africa (MENA) was the most violent region, accounting for more than one third of all global deaths, followed by Sub-Saharan Africa (SSA) with almost half a million deaths. The terrorism figures as per the GTD are presented in column 2, the global total for this period is just under 300,000. Terrorism was also most prevalent in the Middle East and North Africa, accounting for about 42 percent of all terrorism deaths in the GTD. The region least suffering from terrorism is Latin America and the Caribbean, followed by "the West" with a death count of about 4,400. While we assume zero for the GED figure for "the West" (due to GED drawbacks described in the Methods section), it is of note that GTD number is higher than the "raw" GED figure of 3,653. Column 3 lists the "pure terrorism" estimated using the MELTT method and Column 4 the "pure terrorism" estimates based on the TAC method. As discussed above, the total MELTT estimates are higher than the TAC numbers.

Table 1: Total fatality estimates for the years 2000–2018

Interventions	*GED (1)*	*GTD (2)*	*Pure terror MELTT (3)*	*Pure terror TAC (4)*	*Collective Violence MELTT (5)*	*Collective Violence TAC (6)*
The West	0	4,371	4,371	4,371	4,371	4,371
Eastern Europe	31,159	6,089	4,725	4,502	35,884	35,661
Latin America and the Caribbean	81,621	3,672	2,882	1,802	84,503	83,423
Asia	387,072	95,278	73,359	43,223	460,431	430,295
North Africa and the Middle East	585,080	123,078	95,180	86,805	680,260	671,885
Sub-Saharan Africa	466,930	63,109	39,460	18,936	506,390	485,866
World	1,551,862	295,597	219,977	159,639	1,771,839	1,711,501

Notes: The GED estimates for "the West" are 3,653. As stated in the Methods section we assume zero GED deaths for "the West". Columns 5 and 6 provide estimates for collective violence, column 5 is the sum of columns 1 and 3, column 6 is the sum of columns 1 and 4.

[14] Here we refer to the 2013 data since the TAC project does not span 2014.

In column 5 and 6 we present estimates of collective violence deaths, where the estimates use MELTT and TAC estimates, respectively. We estimate that the number of people who died as a result of armed conflict and terrorism to be between 1.71 and 1.77 million people. Note that, given the magnitude of these numbers, our assumptions regarding the difference of death estimates between the GED and the GTD for "the West", an overwhelmingly peaceful and secure region, makes very little difference for the total estimates of collective violence.

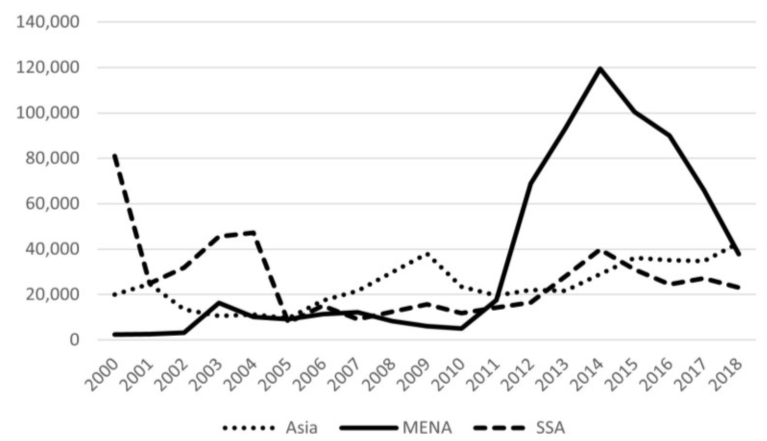

Figure 3: Integrated regional annual fatality estimates due to collective violence based on TAC

In Figure 3 we investigate the time series of our collective violence death estimates for the three most violent regions: the Middle East and North Africa, Asia, and Sub-Saharan Africa. Here we use the MELTT estimates (the TAC estimates are qualitatively similar). In the early 2000s Sub-Saharan Africa had relatively high death per annum counts, with over 80,000 deaths per year. These numbers have declined to about half in 2014 and have further declined toward the end of the period. For Asia, the millennium started with relatively low numbers of about 20,000,however, by 2018 this had doubled. Up until 2011 the Middle East and North Africa had mostly lower death counts than the two other regions, however, in 2014 collective violence killed almost 120,000 people. These figures had come down by 2018 but the Middle East and North Africa remains a very violent region.

Conclusion

To assess progress for SDG 16.1, the United Nations has suggested the measure of conflict-related deaths. We argue that the focus on conflict as state based armed conflicts, or wars, results in an undercounting of violent deaths. Instead, we suggest also considering deaths from other forms of collective violence, such as one-sided violence and terrorism. This type of collective violence is not mentioned in the U.N. targets but exploiting existing data sources could help to provide a more accurate number of deaths caused by armed organized groups.

In this article we discuss the available data sources and suggest that the commonly used social science data provided by UCDP suffer from underreporting bias. Alternative public health data tend to provide higher death counts, but the lack of a common methodological approach make it impossible to add up counts from different countries. The WHO provides data on victims of collective violence, but they are not provided for every year and there is a lack of information on the model on which the estimates are based. It is instructive to compare the numbers for 2015, because we have GED, GTD, and WHO data, as well as estimates from MELTT; additionally, the last year (2013) of the TAC project can still serve as a useful benchmark. For 2015 the WHO estimates about 186,400 collective violence deaths for this year. This is considerably higher than the high estimates from the GED, at about 147,200 deaths. We suggest augmenting the GED with information from other global event databases recording fatalities of collective violence and use the terrorism deaths from the GTD. However, augmenting does not simply entail adding terrorism deaths to conflict deaths, since armed conflict and terrorism are difficult to distinguish both theoretically and in data collection. We use two recently developed methods to identify deaths from "pure terrorism", i.e., deaths that occurred due to terrorism outside of organized armed conflicts. Donnay *et al*. (2019) suggests a comparison of the individual events—resulting in an estimate of about 175,000 deaths due to organized conflict and terrorism worldwide in 2015. The method by Fortna *et al*. (2022) compares the violence committed by insurgent and terrorist groups—this provides an estimate of about 167,000 deaths. Note that although both estimates are higher by design than the armed conflict death counts (GED), they are still lower than the public health counts (WHO), thus our estimates fall between a plausible upper and lower bound.

As discussed, our estimates have to rely on a number of crude assumptions, and we see our study as a first suggestion of how deaths from collective violence may be quantified. One possible extension of our work is to enlarge the actor taxonomy of the MELTT protocol to cover countries outside of Africa. A further option is to extend the existing TAC project beyond 2013. A third extension is to consider a combination of the two methods, MELTT and TAC, by deriving improved estimates through developing an actor taxonomy usable for MELTT from the TAC. Such methodological advancements have a number of implications for research. Distinguishing "pure terrorism" events from terrorism within organized armed conflict will improve our understanding of terrorism itself, a concept difficult to define and measure. The identification of actors present in both data collections (GED and GTD), will also enable further research of the use of terrorist tactics in armed conflicts. Similarly, the sensible integration of these two databases will benefit violence research, particularly the research of phenomena that are not fully covered by either database, like the targeting of civilians.

In addition, there are a number of closely related questions that open new avenues for research. Collective violence not only kills but also maims.[15] However, there is currently no systematic effort to estimate the number of injuries due to collective violence. An investigation of the number of injured due to organized violence and terrorism would help us to capture the burden of collective violence more fully. In addition, organized violence not only kills people directly through the use of force, but also through malnutrition and disease. There are a number of efforts in the public health literature to estimate the excess death rates due to organized conflict.[16] Global estimates suggest that about 1.8 additional people die due to malnutrition and disease per one direct GED death, most of them are children under the age of five.[17] Based on these recent studies, collaborations between social scientists and public health experts appear promising in establishing more defensible estimates of the human cost of organized violence by including the deaths and injuries from direct violence plus the health implications for the conflict affected populations. These estimates would help the research community and the United Nations to better assess whether we are making progress on the 2030 Sustainable Development Agenda.

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15 Ghobarah et al. (2003).
16 For example, see Bendavid *et al*. (2021) and Wise *et al*. (2021).
17 Jawad *et al*. (2020).

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Appendix

Table A1: Countries and regions included in the analysis (part 1)

Middle East and North Africa	*Eastern Europe*	*West*
Cyprus	Poland	United States of America
Morocco	Hungary	Canada
Algeria	Czech Republic	United Kingdom
Tunisia	Slovakia	Ireland
Libya	Albania	Netherlands
Iran	Montenegro	Belgium
Turkey	Macedonia	Luxembourg
Iraq	Croatia	France
Egypt	Serbia	Monaco
Syria	Bosnia and Herzegovina	Liechtenstein
Lebanon	Kosovo	Switzerland
Jordan	Slovenia	Spain
Israel	Bulgaria	Andorra
Saudi Arabia	Moldova	Portugal
Yemen	Romania	Germany
Kuwait	Russia	Austria
Bahrain	Estonia	Italy
Qatar	Latvia	San Marino
United Arab Emirates	Lithuania	Malta
Oman	Ukraine	Greece
Palestine	Belarus	Finland
	Armenia	Sweden
	Georgia	Norway
	Azerbaijan	Denmark
	Turkmenistan	Iceland
	Tajikistan	Australia
	Kyrgyzstan	Greenland
	Uzbekistan	Saint Pierre and Miquelon
	Kazakhstan	Holy See
		New Zealand

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Table A2: Countries and regions included in the analysis (part 2)

Sub-Sahara Africa	*Latin America and the Caribbean*	*Asia*
Cape Verde	Colombia	Afghanistan
Sao Tome and Principe	Venezuela	China
Guinea-Bissau	Guyana	Mongolia
Equatorial Guinea	Suriname	Taiwan
Gambia	Ecuador	North Korea
Mali	Peru	South Korea
Senegal	Brazil	Japan
Benin	Bolivia	India
Mauritania	Paraguay	Bhutan
Niger	Chile	Pakistan
Ivory Coast	Argentina	Bangladesh
Guinea	Uruguay	Myanmar
Burkina Faso	Bahamas	Sri Lanka
Liberia	Cuba	Maldives
Sierra Leone	Haiti	Nepal
Ghana	Dominican Republic	Thailand
Togo	Jamaica	Cambodia
Cameroon	Trinidad and Tobago	Laos
Nigeria	Barbados	Vietnam
Gabon	Dominica	Malaysia
Central African Republic	Grenada	Singapore
Chad	St. Lucia	Brunei
Republic of the Congo	St. Vincent and the Grenadines	Philippines
Democratic Republic of the Congo	Antigua	Indonesia
Uganda	St. Kitts and Nevis	East Timor
Kenya	Mexico	French Polynesia
Tanzania	Belize	Guam
Burundi	Guatemala	New Caledonia
Rwanda	French Guiana	Papua New Guinea
Somalia	Guadeloupe	Niue
Djibouti	Martinique	Vanuatu
Ethiopia	Montserrat	Solomon Islands
Eritrea	Honduras	Kiribati
Angola	Puerto Rico	Tuvalu
Mozambique	Turks and Caicos Islands	Fiji
Zambia	United States Virgin Islands	Tonga
Zimbabwe	El Salvador	Nauru
Malawi	Nicaragua	Marshall Islands
South Africa	Costa Rica	Palau
Namibia	Panama	Micronesia
Lesotho	Anguilla	Samoa
Botswana	Aruba	Hong Kong
Swaziland	Bermuda	China, Macao SAR
Madagascar	British Virgin Islands	Cook Islands
Comoros	Cayman Islands	
Mauritius		
Seychelles		
Sudan		
South Sudan		
Mayotte		
Reunion		

Table A3: Global sum of victims by year

Year	*GED high*	*GTD*	*Pure terror MELTT*	*Pure terror TAC*	*Collective Violence MELTT*	*Collective Violence TAC*	*Collective Violence WHO*
2000	111,477	4,370	3,468	2,214	114,945	113,691	123,834
2001	56,284	7,706	6,514	5,152	62,798	61,436	
2002	53,439	4,795	3,886	1,580	57,325	55,019	
2003	72,618	3,310	2,559	1,520	75,177	74,138	
2004	69,318	5,716	4,441	3,333	73,759	72,651	
2005	25,116	6,342	4,920	3,962	30,036	29,078	
2006	38,634	9,316	7,306	6,979	45,940	45,613	
2007	36,686	12,824	9,695	9,617	46,381	46,303	
2008	48,003	9,157	6,568	5,493	54,571	53,496	
2009	57,280	9,277	6,651	4,412	63,931	61,692	
2010	40,530	7,829	5,968	4,276	46,498	44,806	59,262
2011	49,912	8,246	6,223	4,676	56,135	54,588	
2012	100,088	15,494	11,569	7,397	111,657	107,485	
2013	128,281	22,280	16,612	12,250	144,893	140,531	
2014	165,544	44,524	31,998	23,800	197,542	189,344	
2015	147,022	38,993	27,936	19,933	174,958	166,955	186,375
2016	129,526	35,236	26,494	19,451	156,020	148,977	
2017	120,040	26,892	19,885	13,875	139,925	133,915	
2018	102,064	23,290	17,284	9,719	119,348	111,783	
Total	1,551,862	295,597	219,977	159,639	1,771,839	1,711,501	

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