Conflict Prevention in Isolated World Ship Societies*

Ore Koren†

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Abstract

Scholars have long argued that so-called "closed societies" frequently experience severe violence perpetrated for political motivations. Living in socioeconomic and political vacuum aboard large world ships – without inter-societal migration, external penetration of ideas, conflict management and peacebuilding by external parties, or even regular communications with the outside world – interstellar societies will be especially vulnerable to internal conflict. In such contexts, enmities can easily fester, nonviolent quarrels can escalate into violent conflict and political disagreement can deteriorate into mass killing of opposition members. Building on recent research, this paper identifies specific factors that could engender conflict on interstellar world ships to offer strategies of mitigation and prevention. The paper begins by discussing four types of conflict on Earth that are especially likely in the context of world ships and listing their relevant socioeconomic and political causes. These pathways are then articulated to operationalize empirical models of violence. The strongest predictors are identified empirically by statistically analyzing large datasets of different conflict types on Earth over the last half century. To do so, computer simulations are first applied to out-of-sample data, i.e., data not used to compile the original models, to cross-validate the relevant strength of the predictors identified in the previous stage. This process is repeated twice, first on a sample of all countries globally for the years 1961–2011 and then again on a sample consisting solely of countries with very high population densities – societies that resemble those most likely to exist on world ships. Finally, literature on conflict mitigation is applied to pinpoint strategies to address causes of conflict identified as having an especially strong impact as societal density increases, including political restrictions, economic inequalities, ethnic divisions and limitations on access to food. By applying lessons from earth societies to interstellar travel, this paper will inform the creation of a sustainable, peaceful governance system for future on-board colonies.

Keywords: Comparative politics; Interstellar travel; Political violence; Conflict management

JEL Codes: D74, B20, P51

Introduction

In his seminal book, Karl Popper [1] argues that "civilization has not yet fully recovered from the shock of its birth – the transition from the tribal or 'closed society,' with its submissions to magical forces, to the 'open society' which sets free the critical power of man...the shock of this transition is one of the factors that have made possible the rise of those reactionary movements which have tried and still try, to overthrow civilization and return to tribalism." Indeed, scholars have long argued that so-called "closed societies" frequently experience severe violence perpetrated for political motivations. For instance, in attempting to explain the causes of mass violence, Gerlach [2] writes that such violence "originates from complex processes deeply rooted in the society in which they happen or by which they are generated." Such societies do not have to be *politically* closed; geographic factors can also isolate societies and cause similar effects. The Gebusi, for example, are a "society of some 450 persons living in the lowland rain forest of south-central New Guinea" [3]. Despite its small size, however, the Gebusi society has one of the highest homicide rates on record.

Excluding unforeseeable and exceptional technological changes, societies living on world ships built for interstellar travel will spend several years and probably decades or centuries in (nearly) complete isolation. Such an interstellar vessel ship will be "a huge, self-contained and self-sustained interstellar vehicle" that "travels at a fraction of a per cent of the speed of light and needs several centuries to reach its target star system" [4]. Assuming a travel speed that is less than 10% the speed of light, which – within humanity's current or projected technological capacities is rather unlikely [4] – such vessels will by necessity be "arks" carrying thousands of people. For instance, a colony ship traveling at 1% c to even the nearest star system, Proxima Centaury, will be expected to carry approximately 10,000 people [5]. A world ship traveling at 0.5% c will require a staggering number of 250,000 individuals [6]. Such massive vessels will be disconnected from other human societies, without the ability to receive or send out migrants, gain from ideas developed externally or from external economic

exchange, or even communicate with the outside world. In such contexts, enmities can easily fester, nonviolent quarrels can escalate into violent conflict and political disagreement can deteriorate into mass killing of opposition members. As humanity has yet to deploy such a sizable vessel, this paper surveys research on different types of conflict within earth societies. It uses these evaluations to identify important predictive indicators of violence applicable to interstellar contexts and offer some relevant strategies of prevention and mitigation.

Causes of Conflict in Earth Societies

This paper focuses on four different types of conflict that have been, unfortunately, prevalent throughout human history: nonviolent civil disobedience, coups d'état, civil war and mass killing. Drawing on the relevant bodies of research, salient predictive indicators for each conflict type are identified below. To ensure that the models do not omit potentially salient causes, each of the indicators identified in respect to at least one conflict type is included in all models. For summary purposes, the salient predictors of each violence type are reported Table 1.

Nonviolent civil disobedience

Nonviolent civil disobedience refers to organized political campaigns waged by civilians or opposition parties against the regime using primarily nonviolent methods to achieve a "maximalist" aim (e.g., regime change, secession) [7], a substantive number of which have occurred since 1945. Civil disobedience campaigns differ from political protests, which are common in democracies and are aimed at a specific policy or politician. Civil disobedience campaigns, like civil wars, have a "maximialist" aim – to remove or completely reconfigure the entire political system, or to achieve political autonomy. As such, nonviolent civil dis- obedience is somewhat akin to a civil war, but differs in that it is carried out using primarily nonviolent methods. On a world ship, nonviolent civil disobedience – if it occurs – will likely be the least threatening form of conflict. It is important to emphasize, however, that in contrast to other types of peaceful protest wagers of such civil disobedience campaigns will ultimately seek

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to remove or completely alter the entire political system on the ship. Therefore, despite its relatively peaceful nature, civil disobedience should nevertheless be considered as a possible danger when applied to isolated world ship contexts.

Extant research highlights several determinants of nonviolent civil disobedience. The first is the level of political openness within a given country. Authoritarian regimes' behavior generate forceful civilian response, which frequently assumes a nonviolent form due to the fact that violent resistance frequently "backfires" [7]. Another potential cause of civil disobedience is food shortages. Rising food prices or strong decreases in food production frequently result in mass protests [8]. Third, industrial and economic development facilitate the ability of individuals and groups to take collective action, which in turn create pressures for more political and economic participation [9]. Similarly, higher population densities, especially in urban areas, improve the ability of individuals to interact and communicate, thus further facilitating the formation of a nonviolent opposition movement [10].

Coups d'état

Coups d'état are situations where an organization or a group of political elites seeks to remove a given country's incumbent by force or via otherwise irregular means [11]. Frequently, such coups are arranged and carried out by the military, especially in weaker countries or states where the military is not professional and is deeply ingrained in the state's political institutions. Coups d'état can therefore be a dangerous form of instability on world ships. Assuming that these ships will have some form of a (quasi) military leadership as is the case with modern-day vessels, then enmities within the officer elite can fester. Over decades or centuries of travel, such divisions can generate factions within the leadership and might result in an attempt of one faction to remove another from power.

Four potentially salient causes of coups d'état have been highlighted by extant research. The first is the professionalization of the military, or lack thereof. Civilian control over professionalized militaries can be more easily established, compared with regimes where legal and institutional restrictions are used to limit military power [12]. Second, governments

that fear a coup d'état might increase military spending to pacify the military [13], making military expenditure a potentially important predictor. Third, states that have a better capacity to exercise control within their borders are more resilient to coup attempts [14]. These states have more dynamic economics and a history of social mobilization, but also the infrastructure to provide benefits and correspondingly tax rural areas. Finally, some research argues that ethically or religiously divided states are also more susceptible to a coup d'état as a result of electoral competition and contentious politics [15]. In these situations, political elites might draw on the power of their respective groups, especially as it pertains to military representation, to mobilize against the government.

Mass Killing

Mass killing refers to the intentional elimination of a large number of civilians, i.e. non-combatants, for political purposes. The definition of mass killing covers political purges, ethnic cleansing, genocide and any other mass categorical campaign that falls on this violence spectrum. Considering the scale of deaths involved, as well as the infrequency of such campaigns across time, mass killing will be unlikely on an interstellar world ship, but the severity of the consequences means that the possibility of such events nevertheless merits attention. World ships will have high population densities, where personal spaces are limited. Considering these and other stakes – think, for instance, of the notion of an "interstellar genocide" – it is worth evaluating some useful predictors of mass killing in this paper, especially when using a relatively low threshold of noncombatant deaths to define such campaigns.

Research into the causes of mass killing has identified several explanations for the onset of extreme violence. The first exposition associates mass killing with ongoing civil war. According to this perspective, armies fighting a guerrilla warfare might use mass killing as a strategy of "draining the sea with the fish" to destroy the rebels' sources of support [16]. A second explanation revolves around the role of discriminatory politics and elite manipulations. States with ethnically-nationalistic founding narratives are more susceptible to mass violence in particular contexts, especially when the state already discriminates against a

particular group [17]. A third argument, which has also fallen from grace in recent years, emphasizes "ancient hatreds." Countries where an ethnic majority group carries historical grievances against a second, usually smaller, ethnic group, mass killing arises as a manifestation of this hatred [18]. Finally, some studies identify linkages between the abundance of profitable natural resources and mass killing. These studies argue that groups with more natural resources attract criminals and other recruits who join for profit rather than because they support the group's aims and are thus more likely to terrorize civilians for extraction of profit and due to low discipline [19].

Civil war

Civil war, an internal struggle within the state between the government and at least one armed non-state group is probably the most well-known form of intrastate conflict. Such wars can last anywhere from weeks to decades and frequently arise as a result of a failed coup d'état or violent forms of electoral politics. While a full-scale civil war with thousands of casualties in the same vein as the American Civil War or the wars in former Yugoslavia will be unlikely aboard a world ship, lower levels of armed conflict intensity are a possibility, especially if a coup d'état – successful or not – occurred.

There are several possible civil war scenarios that are relatively frequent in earth societies that are applicable to interstellar world ships. The first scenario involves centrist conflicts, i.e., civil wars fought to take control over the government. On interstellar world ships, in this situation violence will be waged to take power away from staff officers and the captain, or – as discussed below – the elected body that supervises the society's day-to-day operations. The second scenario is a secessionist conflict, i.e., a war fought to gain independence over some part of the country. On a world ship, this might involve violence used to establish autonomy over one part of the ship, especially on vessels composed of several integrated modules or cells [4].

The extensively rich literature on civil war highlighted several potentially salient determinants. The first explanation revolves around ethnic and religious enmities. According

to this view, different ethnic groups come t "fear" each other, and embark upon an arms race – whereby each groups start accumulating weapons and build its military capacity – that culminates with conflict [20]. Recently, however, this notion has been replaced with arguments that emphasize two different factors. One is state capacity. According to this argument, civil war erupts not in countries with ethnic or religious divisions, but rather in states that cannot exercise effective control over their peripheries, which facilitates the formation and persistence of rebel groups [21]. A second approach argues that rebels seek to secure lucrative natural resources to generate revenues [22]. This is especially true for regions where oil deposits exist, as the populations residing there hope to secede and monopolize oil production. Finally, two additional explanations emphasize the role of conflict history – countries that already experienced civil war are much more likely to experience it; and the role of authoritarian rulers, which – by repressing civil disobedience might cause a full-scale civil war, as happened recently in Syria [23].

Other causes

Research on political violence and its causes highlighted some other salient predictors, the most important of which are education levels and infant mortality [24]. However, these are not included in the analyses below, as individuals residing on future world ships will likely have at least a high school education – considering necessary skills required to live on and operate such vessels – and enjoy access to efficient health facilities.

Table 1: **Salient Determinants of Political Violence**

(1) **Nonviolent disobedience**	(2) **Coups d'état**	(3) **Mass killing**	(4) **Civil war**
Regime type	Professionalized military	Civil war	Ethnic/religious enmities
Food shortages	Military spending	Discriminatory politics	Low state capacity
Industrial/economic development	Low state capacity	Ethnic enmities	Natural resources
Population density	Ethnic divisions	Natural resources	History of conflict
			Authoritarian politics

Empirical Results

What will be the most likely causes of conflict on interstellar world ships? This question can be answered by referring to Fig. 1. Each plot in Fig. 1 charts (i) the predictive power of each indicator in the full sample against, (ii) its predictive power in the high population density sample, across the four social conflict types. The data used for calculating these models and the methods used for identifying each model's predictive power are discussed in the Supporting Information file due to space constraints. Briefly, this approach relies on receiver-operator characteristic (ROC) curves, which measure the ratio of events the model correctly predicts to events the model fails to predict, with a perfect model having an area under the curve (AUC) that equals exactly one [25]. The underlying statistical analysis is performed on out-of-sample data obtained via k-fold cross-validation using logistic regression in two stages. In the first stage the sample analyzed includes *all countries* – large and small, more or less densely populated – over the 1961–2011 period. In the second stage the same models and approach are used, only this time the sample analyzed is limited to *high population density countries*, i.e., countries that were above the 75th percentile in terms of their average population densities for the 1961–2011 period (a list of these countries is provided in the Supporting Information file). Each of the plots reported in Fig. 1 thus identifies the predictive indicators of conflict that are most likely to gain in importance as societal density increases.

For nonviolent civil disobedience, the strongest predictor is political openness – $Polity2_t$ – whose impact on the fully specified model's predictive power increases from ∼3% in the full sample to ∼5.6% in the high density sample. This supports the argument discussed above that the utility of such campaigns increases in more authoritarian regimes. The second predictive indicator whose impact increases in high population density contexts is wheat availability, *wheat (kg pc)$_t$*. Again, this finding is in line with research into the relationship between food availability and (urban) unrest, which finds that shocks to food availability and high food prices increase the frequency of protests and riots.

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In the case of coups d'état, the predictive impact of ongoing civil war – the strongest predictor – increases from ~1.5% in the full sample to more than 4% in the high population density model. These findings are in line with research that finds that such events frequently occur in times of war. Additionally, the predictive impact of both *maize (kg pc)$_t$* and *oil prices$_t$* increases from zero in the full sample to about 1% in the high population density sample, which follows some research on the relationship between food availability and anti-regime violence.

For mass killing, ongoing civil war seems to produce to strongest predictive impact in both samples, although its strength decreases as one moves from the full (~8%) to the high density sample (~3%). However, the predictive impact of both food availability indicators – *wheat (kg pc)$_t$* and *maize (kg pc)$_t$* – increases from zero in the full sample to approximately 2.1% and 1.5%, respectively, in the high population density sample. This suggests that food scarcities can increase the probability of violence against civilians, especially where strong pressures on consumption already exist, e.g. high population density areas. Finally, the predictive power of oil prices (or other relevant natural resources) and GDP per capita (economic inequalities) also increase as one moves from the full to the high-population-density sample from approximately zero to ~1.5%.

For civil war, the predictive impact of several indicators increases in the high population density samples. *GDP pc$_t$* shows the strongest – a tenfold – improvement in predictive power, from ~0.75% in the full sample to ~7.5% in the high density sample. This finding is in line with studies that show that civil war frequently arises in countries with weak infrastructure and low development, although it also diverges from this research in that the latter emphasizes that such issues affect civil war incidence in *larger* countries. The indicator *natural disasters$_t$* also shows a strong predictive improvement, from a negative effect in the full sample to about 3.5%in the high population density sample. Previous research on the relationships between climatic variability and war did argue that natural variations can impact conflict incidence but again, these studies focus on largely rural and

agrarian countries. The lag of the dependent variable and the indicator *eth. fractionalization* both show an increase in predictive strength from about 0.5% and 1.5%, respectively, in the full sample to ∼2.5% in the high population density sample. Both conflict history and ethnic cleavages were identified as potential causes of civil war in extant research, although the latter became repeatedly disputed in recent years. Finally, both oil prices and military expenditure show mild improvement in predictive impact of approximately 0.5%, although this change is substantively negligible.

The *k*-fold cross-validation exercises reported in this section and especially the results shown in Fig. 1 identify several important determinants of social conflict – ranging from nonviolent civil disobedience to mass killing and civil war – that are relevant for interstellar world ship contexts. Focusing on the high risk factors shown in Fig. 1, the ensuing section offers different strategies to mitigate and prevent their effect, with a focus on sustainability in the context of future interstellar travel.

Strategies of Mitigation and Prevention

Having identified some important predictors of violence, this section offers specific approaches to mitigate and ultimately prevent the impact of these predictors within the context of interstellar world ships.

Political openness

In the models above, political openness showed the greatest change in predictive impact between the full and high population density samples for the dependent variable *nonviolent civil disobedience$_t$*. Democratization improves individual wellbeing and provide civilians with a variety of channels through which they can voice grievances and concerns [26]. Thus, while protests are common in democracies, civil disobedience campaign with a "maximalist" aim

Figure 1: Change in Each Indicator's Predictive Strength Between the Full and High Density Models

Civil disobedience

Mass killing

Coup d'état

Civil war
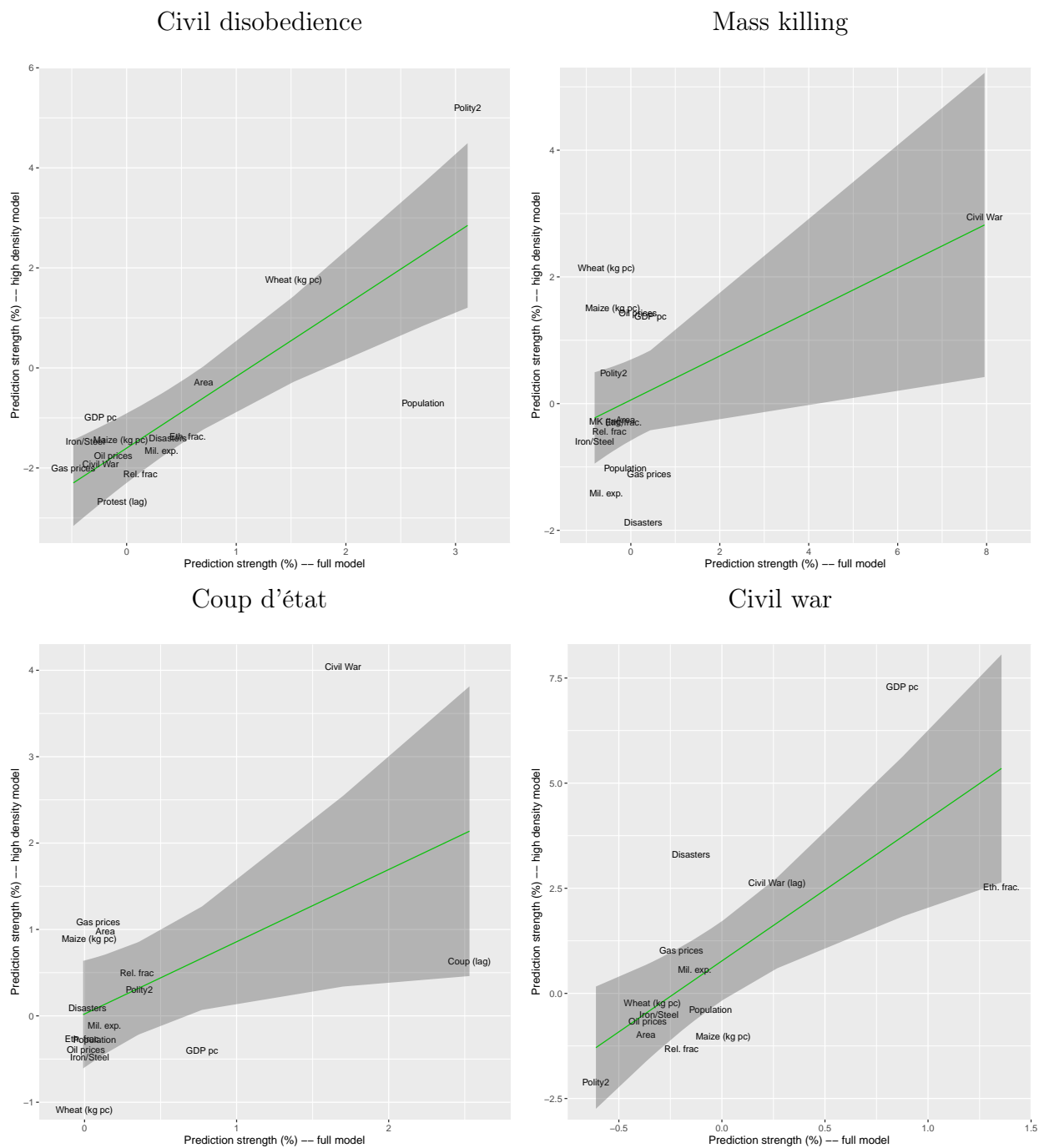
– i.e., campaigns designed to ultimately remove the regime or to achieve autonomy for a particular region – are rather rare.

Whether formed by a military organization such as the United States Air Force, a government agency such as NASA, or a private organization such as Mars One, the command structure of interstellar world ships will likely follow that used in conventional crafts. Such a system assigns a senior officer, hereon "captain," to command the vessel and be the ultimate decider on any policies and issues transpiring on board. Senior and junior officers and specialists generally assist the captain, with the crew's families – if present – being assigned a passive role [27].

The analyses presented above suggest that such an approach would not be a good fit for an interstellar vessel. Having a single decision-maker without checks on his or her power, whether this position is hereditary or conferred via elections, has not proven to promote stability in high-density societies. Granted, having some sort of overall, perpetual command structure will probably be necessary considering the challenges posed by decades or centuries of travel. Nevertheless, to promote a prosperous society and ensure peaceful cohabitation, an interstellar world ship will likely require a political system that does not rely on the whims of a "benevolent dictator."

Currently, the political model that best fits both criteria is a constitutional monarchy, its interstellar variant being "constitutional captaincy." In a constitutional monarchy, a formal sovereign exercises authority in accordance with a constitution or a set of unwritten foundational laws [28]. The monarchic aspect provides some form of "natural" stability, while the constitutional aspect guarantees a political system of elected officials– usually a parliamentary one – that manages the interstellar society's day-to-day aspects and is directly responsible for the well-being of its subjects. Examples of modern-day constitutional monarchies (and their variants) are the UK, Denmark, Luxembourg, Sweden and Spain, among others. Such combined monarchy-parliamentary systems are also significantly more stable than presidential ones [29]. In interstellar world ships, the role of the monarch, or

ultimate decision-maker, will be filled by the captain or a similar senior officer, a position that can be either electoral (e.g., for life) or inherited. However, management of day-to-day affairs, including security, will likely be left to a body of elected officials. Such a system will allow world ship residents to voice concerns and hold officials accountable (in contrast to a military vessel), while maintaining a formal command structure.

Development and Capacity

Another variable that shows a (strong) change in predictive power between the full and high population density samples in both civil war and, to a lesser extent, mass killing models is *GDP pc$_t$*. In conflict research, GDP per capita is frequently used to approximate a given state's bureaucratic and military capacities, its ability to operate in tough terrains (e.g., mountainous areas) or its development levels. These factors directly relate to a given society's economic capacity, income inequality levels and the economic well-being of its citizens.

Unlike Earth societies, which can persist even with extreme poverty and corruption, interstellar societies will require a relatively high economic capacity to survive. Most raw material will be obtained in an undifferentiated state and then processed to create necessary secondary products, ranging from water to computer screens [30]. Moreover, again unlike in Earth societies, *physically* expanding the interstellar world ship's economy will be complicated if not impossible. To achieve feasible economies of scale and ensure that those who control the processing facilities do not enjoy monopoly over the means of production – a factor that has been repeatedly associated with conflict – interstellar societies will need to find alternative ways to develop their economies.

The answer can be found in the notion of a virtual economy. Most stocks are traded virtually nowadays, and most currency used in the global economy is never printed. Many profitable services have no tangible product (e.g., Facebook). Higher levels of "virtual wealth" offer several advantages. They can stimulate consumption and depress saving, thus raising aggregate demand and output [31]. They allow individuals to make gains by participating in an informal economy, a fact that has both advantages and disadvantages [32]. Without the

necessity for a large-scale industrial production and conversion of elements, the vast majority of individuals residing on interstellar world ships – like their counterparts in modern developed countries – will be part of the services sector. Effective economic policies on such world ships will thus need to facilitate participation and enterprise in different virtual endeavors, ranging from individuals who offer text-editing services to "unicorn start-ups." This will help ensure that the world ship's government can (i) guarantee sustainable employment for the largest number of individuals possible, (ii) tax these endeavors and use revenues to improve the society's well-being and (iii) exercise sufficient control on all parts of society to prevent grievances from festering in uncontrolled parts of either the physical or virtual society and turning into social conflict.

Ethnic Cleavages

The analyses above show that at least in the case of civil war the predictive power of ethnic cleavages – measured by the indicator *eth. fractionalization* – increases in the high population density sample. While numerous recent studies argue that ethnic cleavages operate as a proxy for other factors, such as development and political openness, their strength as a predictive indicator suggests that some strategies to mitigate the potential effect of such cleavages should be considered.

Some might interpret the above finding to suggest that interstellar societies should be ethnically homogeneous. This, however, is unlikely to prevent conflict onset. Beyond the long-term genetic issues that might arise within an ethnically homogeneous society such as genetic drift and the emergence of genetic diseases such as Tay-Sachs, there are also the moral implications of creating a society of "*Übermenschen*" to serve as humanity's interstellar pioneers. Moreover, ethnicity and ethnic cleavages are frequently an endogenous social construction rather than an exogenous factor, created or at least strongly manipulated and redefined by elites or particular extremist groups [33]. As a result, ensuring an ethnically homogeneous society on interstellar world ships will be unlikely to mitigate the determinedly effects of ethnic cleavages, at least over the long-term.

An alternative approach and one that is arguably more likely to generate a society that is robust to ethnicity-based conflict is multiculturalism. The multicultural citizenship approach relies on the notion that "[a] comprehensive theory of justice in multicultural states will include both universal rights, assigned to individuals regardless of group membership and certain group-differentiated rights or 'special status' for minority cultures" [34].

Multiculturalism thus gives different groups room to practice their traditions within the realm of a liberal society. Combined with the existence of an effective political system as discussed above, a multicultural approach tolerates – if not encourages – the practices of different ethnic groups, even if these sometimes go against the tenets of liberalism. An example of such an institution is the Canadian Multiculturalism Act, an act of parliament that legally enforces the right of different groups for particular practices that might be considered illiberal, such as customs that discriminate in property rights. The ability to create a more flexible form of liberalism helps to ensure that the participation of groups in the public domain is largely devoid of the enmities that might exist in societies where policies are either designated along ethnic lines or completely negate any notion of ethnic traditions, which can mitigate the impact of ethnic cleavages on conflict.

Natural disasters

In the case of civil wars, at least, the analyses presented above suggest that the number of natural disasters has some substantive predictive impact. There are several pathways by which this effect occurs. One is by impacting food production and consumption levels, which can push individuals to participate in rebellions as an alternative to free-market solutions [35]. Another pathway, although a more contested one, is that severe natural disasters can increase conflict frequency by inducing migration, which is not possible in a strictly closed society. Population movements across different regions can increase the risk of subsequent conflict in both host and origin countries [36].

A crucial aspect of natural disasters is that they are completely exogenous in respect to conflict, i.e., cannot be caused by violence. In the models above, natural disasters are

illustrative, perhaps, of what might happens in cases of similar exogenous crises on a world ship, such as nuclear meltdown or a collision with an interstellar body [37]. The leadership's response to such events can amplify intra-societal grievances especially considering that no external intervention will be possible.

Unfortunately, research on policy responses to natural disasters does not offer clear mitigation strategies that could be applied to interstellar travel. An important aspect of disaster aid on Earth is that sudden infusions of outside aid and expertise can compromise existing community public health operations by setting up parallel systems with different norms and resources, an unlikely event in outer space. Reducing vulnerabilities to grievances and strengthening the resilience of local systems within the world ship can inform strategic responses to such crises. Health care personnel will also benefit from adequate preparation for situations that become increasingly politicized, especially within the (quasi-)militarized societal structure that might be necessary on an interstellar world ship [38].

Food availability

The final factor discussed here is limitations on food availability and access. Both *wheat (kg pc)$_t$* and *maize (kg pc)$_t$* show improvement in predictive model strength in several cases although wheat – whose effect is noticeable across three of the four models – more so. This is not surprising considering that studies have shown that variations in food availability, or even anticipations of future variations, increase the probability of social conflict [39, 40].

The easiest course of mitigation in respect to food availability variations is to ensure equal access to food for all world ship residents. Frequently, however, this is not possible. Even with a plant-based diet, ensuring sufficient caloric intake for all residents in a sustainable way is likely to be challenging. Partly, this is a matter of effectively managing available space. Urban gardening, for instance, is a powerful technique to increase food security in dense population contexts [41], especially if nitrates could be externally collected from the interstellar environment and used as fertilizer. However, frequently limitations on food access can persist even if plenty of food is available, for instance, if a distribution hub malfunctions

or part of the ship disconnects from the mainframe.

These issues suggests that sustainable food production on an interstellar world ship should take place at least partly at the household level. One way to achieve this goal is by relying on new types of diet. Insects, for instance, are rich in proteins and low in fats, require little space and materials to be produced in large quantities and produce very low pollution compared with livestock and even some staple crops. While the necessity to preserve space in interstellar world ships means that allocating each household enough space for a vegetable patch will be complicated, insects can be easily grown within moderate apartment spaces. This means that the core staple of the world ship's food production system will be highly decentralized and hence more robust to crises and shocks. All these factors make insects an especially effective food source for interstellar travel [42].

The reliance on decentralized production of insects as an easy source of protein can be enriched by the centralized production of staple crops and livestock, which will create a mixed nutrition system that is highly robust to production shocks and sudden limitations on access. To create food for home-grown insects, a substrate such as cornmeal will have to be manufactured in a centralized way and then distributed to each household. However, considering the low food demands of insects one bag of substrate will be able to feed a household for months if not years. Thus, in the event of a prolonged interruption to centralized food production, each household will still be able to sustain itself for long periods (assuming it has at least one bag of substrate), thus providing the ship's leadership with ample time to overcome sudden shortcomings and reducing the probability of conflict.

Other predictive indicators

The models above also identify some additional potential predictors of conflict in interstellar world ship contexts, which are not discussed here in detail. For example, although profitable natural resources such as oil and gas show slight predictive improvements for some types of conflict in the high population density sample, these improvements are substantively negligible. Civil war is also a valid predictive indicator of mass killing and coups d'état in

Fig. 1. However, this indicator loses rather than gains predictive strength when shifting from the full to the high population density sample in the case of mass killing, while addressing potential causes of civil war, such as economic development and limitations food availability, should correspondingly ameliorate the impact of such conflicts on coups d'état.

Conclusion

This paper assesses some potential causes of violent and nonviolent conflict on interstellar world ships using a research design that emphasizes the substantive and predictive power of each potential cause rather than its statistical significance. The paper first surveyed the literature to identify a large set of predictive indicators of four violence types: nonviolent civil disobedience, coups d'état, civil war and mass killing. The methodology used to evaluate the impact of these indicators on each conflict type relies on the difference in receiver-operator characteristic (or ROC) curves, expanded to out-of-sample contexts using a k-fold cross-validation approach. The purpose of this analysis is to specifically identify those indicators that increase each model's predictive power in high population density contexts that are likely to characterize interstellar travel compared with a global sample.

It is important to note some potential limitations in these analysis. First, considering the relatively low ratio of events-to-no-event (i.e., ones-to-zeros) on each dependent variable, penalized logistic regressions (e.g., Lasso, Ridge) might be preferred. Using these approaches, however, complicates the substantive interpretation of post-estimation quantities across different variables and specifications. Moreover, in the context of conflict forecasting, simple logit models frequently outperform more sophisticated ones and as a result became the main workhorse of prominent conflict forecasting organizations such as the Political Instability Task Force [43]. Second, scholars recently began to advocate relying on other predictive tools such as precision-recall curves [44]. So far these approaches have been used mainly in mixed-distribution survival models such the split-population Weibull. Nevertheless, future research into the potential causes of interstellar conflict will likely benefit from such tools.

In addition to statistical-computational analyses, this paper also offered and discussed potential strategies for prevention and mitigation. According to these discussions, the ideal world ship society will be modeled after a multicultural, constitutional-monarchic model (perhaps similar to Canada's), rely on virtual modes of entrepreneurship to ensure economic progress and equality and employ decentralized modes of sustenance and emergency response. Insofar as we will be able to anticipate some of the challenges involved with the massive endeavor of interstellar travel in future decades or centuries these findings should yield insights into the feasibility of a world ship and the functioning of the society residing therein.

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