

Pandemic Refuges: Lessons from Two Years of COVID-19

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Abstract

This paper relates evidence from the COVID-19 pandemic to the concept of pandemic refuges, as developed in literature on global catastrophic risk. In this literature, a refuge is a place or facility designed to keep a portion of the population alive during extreme global catastrophes. COVID-19 is not the most extreme pandemic scenario, but it is nonetheless a very severe global event, and it therefore provides an important source of evidence. Through the first two years of the COVID-19 pandemic, several political jurisdictions have achieved low spread of COVID-19 via isolation from the rest of the world and can therefore classify as pandemic refuges. Their suppression and elimination of COVID-19 demonstrates the viability of pandemic refuges as a risk management measure. Whereas prior research emphasizes island nations as pandemic refuges, this paper uses case studies of China and Western Australia to show that other types of jurisdictions can also successfully function as pandemic refuges. The paper also refines the concept of pandemic refuges and discusses implications for future pandemics.

Keywords: global catastrophic risk; refuges; pandemics

1. Introduction

In the study of global catastrophic risk (GCR), refuges have been proposed as a way to reduce the severity of global catastrophe events.¹ Global catastrophe refuges are places or facilities designed to ensure the survival of some portion of the human population and perhaps also certain aspects of human civilization. It is of course preferable that the global catastrophe would not happen in the first place, but if it does, then there is value in assisting survivors. Global catastrophe refuges are of particular value for preventing outcomes that are difficult or impossible to reverse, such as the collapse of civilization or human extinction.

The ongoing COVID-19 pandemic provides empirical evidence of relevance to the study of global catastrophe refuges. COVID-19 is by far the most severe global event to have occurred in recent decades. Whether COVID-19 classifies as a global catastrophe depends on the selected definition.² Regardless, the pandemic is of clear relevance as a case study to inform refuge policy for future

¹ Prior studies of refuges for global catastrophes include Hanson (2008), Jebari (2015), Baum et al. (2015), Beckstead (2015), and Turchin and Green (2017; 2019).

² Definitions of global catastrophe include the death of 10% (Cotton-Barratt et al. 2016) or 25% of the global human population (Morrison 1992), one billion deaths (NRC 2010), a “significant reduction in humanity’s ability to survive in its current form”, especially via breakdown of critical systems (Avin et al. 2018, p.21), and a large and damaging change to the state of the global human system (Baum and Handoh 2014). Under these definitions, COVID-19 does not (yet) classify as a global catastrophe. COVID-19 does already classify as a global catastrophe under the more relaxed standards of Bostrom and Ćirković (2008), who define global catastrophe as events that cause at least millions of deaths or tens of billions of dollars of damage. Schoch-Spana et al. (2017, p.1) define global catastrophic biological risks as “events in which biological agents... could lead to sudden, extraordinary, widespread disaster beyond the collective capability of national and international governments and the private sector to control.” It is unclear whether COVID-19 meets these criteria.

pandemics, including pandemics more severe than COVID-19, as well as refuge policy for other GCRs. Boyd and Wilson (2021) use data from the first nine months of COVID-19 (through September 2020) to evaluate the potential for island nations to serve as refuges during pandemics, drawing on prior work by Boyd and Wilson (2019) and Boyd et al. (2020). Island nations are favored for their geographic remoteness and political cohesion. Boyd and Wilson (2021) find Australia, Iceland, and New Zealand to be the most promising candidates for island refuges.

This paper offers a complementary perspective on pandemic refuges given data from the first two years of COVID-19. Primary analysis covers events through January 2022; a postscript (Section 6) discusses events through April 2022. The paper refines the concept of a pandemic refuge, evaluates the performance of select refuges during COVID-19, and presents implications for future pandemics. The analysis centers on case studies of China and Western Australia, two jurisdictions that have functioned as pandemic refuges during COVID-19 despite not being island nations.³ These cases, combined with broader experience from COVID-19, suggest a new set of considerations for the development of refuges to manage the risk from future pandemics.

2. What Is A Pandemic Refuge?

A dictionary definition of the word “refuge” is “a place or situation providing safety or shelter.”⁴ A pandemic refuge can be defined as a place providing safety or avoiding significant harm from a pandemic. As a starting point, it can be helpful to think of pandemic refuges as places with low medical harm, in particular because the pandemic pathogen has not spread significantly within the refuge. Wider socio-economic effects (e.g. economic disruption, broader health and wellbeing impacts) are also important.

Prior research on global catastrophe refuges—for pandemics and other catastrophe scenarios—has emphasized highly remote locations on grounds that geographic separation will reduce the refuges’ exposure to the hazard and avoid disruptions from desperate outside populations. Proposed locations include outer space (Shapiro 2009), underground or in ice (Baum et al. 2015), underwater (e.g. submarines, Turchin and Green 2017), and islands (Turchin and Green 2019; Boyd and Wilson 2019; 2021; Boyd et al. 2020). Emphasis is often placed on ensuring the survival of some human population even in the face of the most extreme global catastrophe scenarios. The refuge may even be designed to include a “minimum viable population” to ensure the viability of future generations.

Such refuges may be unconventional as a risk management concept, but they are grounded on a sound foundation in the ethics of risk and expected utility. An extreme global catastrophe could cause massive harm to human populations around the world now and into the distant future. Any catastrophe resulting in human extinction would of course be permanent (Matheny 2007). The collapse of human civilization or even a delay in major civilizational progress (e.g., expansion into outer space) could cause major permanent harms (Baum et al. 2019). A global catastrophe refuge could be the difference between survival and extinction, or between the collapse and non-collapse of civilization, or between the recovery and non-recovery of civilization in the event of collapse. Extreme pandemics from either natural or artificial pathogens may be able to cause the collapse of civilization or worse (Millett and Snyder-Beattie 2017; Manheim, 2018). The risk management objectives of a pandemic refuge can thus be articulated as: at a global level providing safety from a pandemic in order to advance the survival of the human population and/or the continuity or recovery of human civilization; and at a local level as minimizing the health and socio-economic impacts on the refuge population. A pandemic refuge could

³ This paper uses the standard geographic definition of an island as “A piece of land surrounded by water”, though places such as Western Australia have a geographic isolation that arguably classifies them as islands in the sense of “A thing regarded as resembling an island, especially in being isolated, detached, or surrounded in some way.” These definitions are from <https://www.lexico.com/definition/island>.

⁴ <https://www.lexico.com/definition/refuge>

advance these objectives on its own or in association with other refuges and/or survivors of regions devastated by the pandemic.

It follows that a pandemic refuge does not necessarily need to avoid all contact with the pandemic. What matters is that the refuge avoid massive harm from the pandemic, including loss of population and socio-economic disruption. The refuge can sustain some exposure to the pandemic pathogen, such as through interaction with outside regions, as long as damage is limited via effective containment of any outbreaks. Indeed, interactions with outside regions may be of high value for the objectives of sustaining or recovering civilization. Conceptually, one can distinguish between “open” pandemic refuges, which permit some interaction with outside regions, and “closed” pandemic refuges, which do not permit any interaction. Closed refuges may provide the highest degree of protection from the pandemic pathogens; the benefits of this should be weighed against the potential harm of ceasing interaction with outside regions.

Meeting its risk management objectives thus requires a pandemic refuge to balance protecting its inhabitants and supporting outside populations. The optimal balance can in theory be derived from the goal of maximizing the long-term success of human civilization, including the persistence and future success of the refuge population and any other survivors. In practice, decisions on refuges may need to consider a variety of other factors, including other normative goals held by political leadership, civilian populations, and other relevant actors which may vary over the duration of a pandemic.⁵ Regardless of the details, the optimal refuge in both theory and practice may tend to have a lower degree of isolation than may be appropriate for other catastrophe scenarios. Instead of locating refuges in exotic locations such as underground, underwater, or in outer space, it may be better to use existing political jurisdictions or other ordinary inhabited regions.

3. Pandemic Refuges During The First Two Years of COVID-19

Pandemics are dynamic phenomena. The 1918 pandemic began mild before evolving into something far more virulent (Andreasen et al. 2008). COVID-19 began very virulent and has evolved into something more transmissible and perhaps somewhat more virulent, the B.1.617.2 (Delta) variant (CDC 2021). At the time of this writing (January 2022), the B.1.1.529 (Omicron) variant is on the rise as an even more transmissible virus that may be less virulent (Gallagher 2021). The story of COVID-19 is still being written. Likewise, insights from it are only preliminary, but can nonetheless be informative for the study of pandemic refuges.

Table 1 shows COVID-19 statistics for the ten most populous countries in the world. Table 2 does the same for the ten island nations that are most highly rated as candidates for pandemic refuges according to Boyd and Wilson (2021). Table 3 does the same for the states and territories of Australia that have at least 100,000 people. The tables include both official and estimated COVID-19 statistics to provide complementary perspectives on the extent of COVID-19 in different locations. Official statistics undercount the extent of COVID-19 because they omit cases and deaths that go unreported. Neither the official nor the estimated data should not be taken as exact; inaccuracies may arise due to biases in testing and reporting or in the models used to produce estimated data. Nonetheless, the data provide at least an approximate indication of the degree of wide variation in prevalence of COVID-19 across a selection of political jurisdictions. The per capita case rate varies across countries by two to three orders of magnitude in both official and estimated statistics.

⁵ On the general challenge of balancing the goal of long-term success for human civilization and other goals held by important actors, see Baum (2015).

Country	Population	Official Cases/100K	Estimated Cases/100k	Official Deaths/100k	Estimated Deaths/100k
China	1,471,280,500	9.26	1,358.33	0.39	0.36
India	1,380,004,400	2,725.95	142,365.82	35.27	212.14
USA	331,002,700	19,552.90	98,556.32	254.90	298.51
Indonesia	273,523,700	1,562.49	53,841.68	52.71	175.58
Pakistan	220,892,500	601.42	123,943.13	13.14	205.58
Brazil	212,559,400	10,820.81	106,200.49	292.18	302.36
Nigeria	206,138,700	121.85	75,969.23	1.51	45.45
Bangladesh	164,689,300	991.44	119,520.54	17.10	134.78
Russia	145,934,500	7,445.47	144,686.65	221.11	460.76
Mexico	128,932,800	3,388.06	138,343.95	233.77	431.66

Table 1. COVID-19 statistics per 100,000 people on 18 January 2022 for the ten most populous countries in the world. Population data are from the United Nations.⁶ Official COVID-19 statistics are from the World Health Organization.⁷ Estimated COVID-19 statistics are from the Institute for Health Metrics and Evaluation, University of Washington School of Medicine.⁸

Country	Population	Official Cases/100K	Estimated Cases/100k	Official Deaths/100k	Estimated Deaths/100k
Australia	25,499,900	5,590.23	57,913.39	10.58	10.84
New Zealand	4,822,200	306.79	632.28	1.08	1.47
Iceland	364,100	13,723.52	72,660.78	12.08	18.30
Japan	126,476,500	1,504.78	10,965.39	14.58	56.10
Cuba	11,326,600	8,821.64	45,167.19	73.64	110.40
Sri Lanka	21,413,200	2,788.16	26,102.95	71.07	84.28
Trinidad and Tobago	1,399,500	7,216.50	65,261.41	228.44	339.85
Malta	514,600	12,436.74	47,148.88	98.34	119.34
Jamaica	2,961,200	3,789.66	78,571.28	85.44	155.21
The Bahamas	393,200	7,693.44	107,527.72	182.84	272.85

Table 2. COVID-19 statistics per 100,000 people on 18 January 2022 for the ten island nations that are most highly rated as candidates for pandemic refuges according to Boyd and Wilson (2021). Population data are from the United Nations.⁹ Official COVID-19 statistics are from the World Health Organization.¹⁰ Estimated COVID-19 statistics are from the Institute for Health Metrics and Evaluation, University of Washington School of Medicine.¹¹

⁶ <https://population.un.org/wpp/Download/Standard/Population>

⁷ <https://covid19.who.int>

⁸ <https://covid19.healthdata.org>

⁹ <https://population.un.org/wpp/Download/Standard/Population>

¹⁰ <https://covid19.who.int>

¹¹ <https://covid19.healthdata.org>

State/Territory	Population	Official Cases/100K	Official Deaths/100k
Australian Capital Territory	432,300	4,734.67	4.40
New South Wales	8,189,300	8,010.54	10.78
Northern Territory	246,300	2,104.75	0.81
Queensland	5,221,200	3,546.98	0.69
South Australia	1,773,200	4,012.69	2.37
Tasmania	541,500	1,953.83	2.40
Victoria	6,649,200	7,152.82	25.48
Western Australia	2,681,600	48.81	0.34

Table 3. COVID-19 statistics per 100,000 people on 18 January 2022 for the states and territories of Australia that have at least 100,000 people. Population data are from the Australian Bureau of Statistics.¹² Official COVID-19 statistics are from the Australia Department of Health.¹³

Tables 1-3 show data on 18 January 2022 to highlight the divergence between Western Australia and the rest of Australia. The Omicron variant was detected in November 2021 and was spreading widely throughout most jurisdictions by December 2021. For a variety of reasons, the rest of Australia relaxed its border policies in December 2021, allowing most Australians to travel by Christmas. Prior to January 2022, all of Australia served, to varying degrees, as a pandemic refuge, as can be seen from the corresponding COVID-19 statistics. Western Australia relaxed its own border policies in March 2022. Mid-January 2022 is an indicative date showing the difference between Western Australia and the rest of the country.

Jurisdictions with low prevalence of COVID-19 may function as pandemic refuges. With little or no spread of COVID-19, these places provide safety from the pandemic. As discussed in Section 2, pandemic refuges avoid all types of harm from the pandemic, including medical harm and other harms such as socio-economic disruption. Therefore, medical statistics may provide a limited understanding of the state of affairs in these jurisdictions. With this in mind, the following sections provide qualitative discussion for the two jurisdictions with the lowest per capita case rate among the jurisdictions included in Tables 1-3: China and Western Australia.¹⁴ These two places do not necessarily have the lowest per capita case rates of all political jurisdictions in the world—consideration of all jurisdictions is beyond the scope of this paper—but they are nonetheless informative examples of jurisdictions that have successfully avoided significant spread of COVID-19.¹⁵

3.1 China

China maintains a “zero COVID” policy and has been described as the last country to maintain such a policy (Wang, V. 2021). This policy involves extensive testing to detect cases, restrictions on the movement of infected people and in some cases entire regions (“lockdowns”), and quarantine for international arrivals (*ibid.*). The policy has also been extended to testing for infections within animal populations and destroying any infected animals—an extreme but possibly necessary biosecurity measure to avoid transmission and further evolution of the virus (BBC News 2022). The policy has been criticized by outside observers as “draconian” (Liu et al. 2021) and a “human rights tragedy” (Wang, Y., 2021), but it nonetheless has been effective at avoiding significant spread of COVID-19.

¹² <https://www.abs.gov.au/statistics/people/population/national-state-and-territory-population/latest-release#states-and-territories>

¹³ <https://www.health.gov.au/health-alerts/covid-19/case-numbers-and-statistics#daily-cases>

¹⁴ Out of all countries in Tables 1-2, China has the lowest per capita case rate according to official statistics and second-lowest (after New Zealand) according to estimated statistics. Outside observers have raised suspicions about China’s reported COVID-19 statistics, in particular that it may be under-reporting deaths (e.g., Birtles 2021), though this does not change the overall picture of China having low overall case and death numbers.

¹⁵ Taiwan is an example of another jurisdiction that has maintained low per capita case rates.

China's success at avoiding significant spread of COVID-19 is remarkable in several respects.

First, China is notable as the country where the pandemic originated and where it first spread. Clearly, China has not managed to avoid all exposure to COVID-19. China has faced additional outbreaks since its initial one, including an outbreak of the more infectious Delta variant (Liu et al. 2021). China's case shows that a refuge can be successful despite having significant exposure to the pandemic pathogen, especially for a jurisdiction willing to bear the cost of extensive restrictions on its population. Likewise, China's case demonstrates the value of pandemic refuges developing capacity to suppress outbreaks and not just avoid them.

Second, China is the world's most populous country and has one of its two largest economies.¹⁶ It is the antithesis of the tiny outposts often considered in the global catastrophe refuges literature. Any catastrophe that leaves China more-or-less unscathed would almost certainly not result in the collapse of global human civilization. China on its own should be much more than enough to maintain the continuity of civilization. (The same applies to other major countries, and potentially even some minor ones.) There would inevitably be major setbacks in any scenario involving severe harm across the rest of the world, but the worst-case scenarios would be avoided.

Third, China is not an island. At 22,457 km, it has the longest land border of any country in the world, and has land borders with 14 countries, which is more than any other country except Russia (CIA 2021a; 2021b).¹⁷ China's land border has played a role in the pandemic. For example, Zhang et al. (2021) describe the reintroduction of COVID-19 to China via two undocumented immigrants crossing the land border from Myanmar and the subsequent testing of over 280,000 local inhabitants. Being an island may confer geographic advantages for pandemic refuges, but it is clearly not essential and may not even be a particularly important factor.

Fourth, China is authoritarian. It is rated as one of the least free countries in the world.¹⁸ Its particular government has been described as responsive authoritarianism (Heurlin 2017); its handling of COVID-19 may likewise be interpreted as responsive to domestic concerns, especially concerns about its less successful handling of the initial COVID-19 outbreak in Wuhan (Wang, V. 2021). Responsiveness aside, it is nonetheless the case that China's authoritarianism has helped it maintain extensive public health restrictions. This is a notable data point for the study of global catastrophic risk governance, which has considered authoritarianism and other low-freedom regimes as something that can both increase and decrease the risk (Caplan 2008).

Fifth, as with many Asian countries, China has a culture that is more collectivist and less individualistic. Collectivist culture can be advantageous for managing infectious diseases because people in collectivist cultures tend to conform with the behavior of others in their group and avoid contact with outsiders; it has even been proposed that high exposure to infectious diseases over long periods of time causes collectivism (Fincher et al. 2008). China's success as a COVID-19 refuge is consistent with the theory that collectivist culture is advantageous during infectious disease outbreaks.

Sixth, China is one of the countries that developed a vaccine for COVID-19. While none of the existing COVID-19 vaccines have managed to end the pandemic, they have significantly reduced its harm. In scenarios in which China provides refuge from more severe pandemics, there is likewise hope that it could develop a vaccine to end the pandemic or at least mitigate its harm.

3.2 Western Australia

Western Australia has the lowest case numbers in Australia and is notable as a subnational jurisdiction

¹⁶ China currently has the largest gross domestic product (GDP) by purchasing power parity and the second largest (after the United States) nominal GDP.

¹⁷ According to the CIA World Factbook, China and Russia both border 14 countries. This does not include disputed territories that are unrecognized by the United States, such as Abkhazia and South Ossetia, both of which border Russia.

¹⁸ For example, by the Freedom House, <https://freedomhouse.org/countries/freedom-world/scores>.

in which COVID-19 policies have diverged from the rest of its country. All of Australia has had near-zero cases for extended stretches of the pandemic, and case numbers remained low (prior to arrival of Omicron) everywhere except New South Wales, Victoria, and to a lesser extent the Australian Capital Territory. At the start of the pandemic, public health measures were uniform across Australia. Western Australia only emerged as a distinct pandemic refuge in the second year of the pandemic and in particular following the spread of Omicron in Australia starting in late December 2022. As with other parts of Australia, Western Australia had a small number of COVID-19 cases early in the pandemic but then maintained near-zero case numbers until it eventually ended its refuge policy in March 2022.¹⁹ Here, Western Australia is considered due to its performance during COVID-19 and its potential as a refuge in future pandemics.

As with China, Western Australia is not an island. It is a state of Australia, covering the western third of the country with an area of approximately 2.6 million km² and a population of approximately 2.5 million (ABS 2016). Although it is not an island, it is geographically remote and functions much like an island. Its performance as a refuge during the COVID-19 pandemic (Table 3) can be explained through a range of factors in addition to its geographic remoteness.

First, Western Australia has maintained a strong economy while avoiding the spread of COVID-19. Western Australia has an export-oriented economy dominated by mining (47% of gross state product), in particular iron ore production. It produces more than half of all of Australia's exports and was the only state economy to grow in 2019-2020 (Western Australia 2021). Importantly, it has been able to maintain robust exports while avoiding significant spread of COVID-19. This shows that a pandemic refuge does not need complete isolation from the rest of the world. Furthermore, Western Australia's ability to maintain a robust economy appears central to its commitment to an otherwise high degree of isolation from the world. Indeed, a leading voice in the push to reopen Western Australia is its tourism industry, which has suffered greatly from Western Australia's isolation (Perpitch 2022). As Boyd and Wilson (2021) observe (see also Farzanegan et al. 2021; Hoarau 2021; Yang et al. 2021), tourism has been a significant cause of the spread of COVID-19 and also a significant source of economic struggle during the pandemic, including for many island jurisdictions. This experience shows that the character of a jurisdiction's economy can factor significantly into its viability as a refuge. However, it is worth considering how this experience applies to more extreme pandemics, for example if an export economy could spread a more infectious pathogen or if the collapse of outside economies eliminated demand for export products.

Second, Western Australia has historically strong quarantine and biosecurity policies (Anderson et al. 2017; MacDonald et al. 2020). These historic strong quarantine policies, and a rapid use of evidence from other jurisdictions, have likely assisted its quarantine performance as it relates to COVID-19 border control and containment measures (Codreanu et al. 2021). Western Australia is further building dedicated quarantine facilities for future use, following the design successfully employed in the Northern Territory (Grout et al. 2021). This experience suggests that pandemic refuges may tend to succeed if they are in jurisdictions with a strong preexisting commitment to avoiding infectious disease and a high degree of technical competence in doing so.

Third, Western Australia is socially isolated with a strong secessionist history (Lecours & Beland 2019). This may contribute to the political palatability of hard borders even to domestic in-migration within Australia. It is worth considering how social isolation can contribute to the success of potential refuges noting that no quarantine system will be 100% effective and thus the size of migration (either of citizens returning home or otherwise) is likely to contribute to the number of incursions of the virus into the general population. While the remaining states and territories within Australia have opened domestic borders, under pressure from constituents to have freedom of movement domestically,

¹⁹ Case numbers actually began rising in Western Australia before it opened its borders. See Section 6 for discussion.

Western Australia remained closed until March 2022. The rates of infection reported in Table 3 reflect this strong difference in subnational border policies.

4. Implications for Pandemic Refuge Theory and Policy

4.1 What the COVID-19 Evidence Says

Perhaps the most important implication of the evidence from two years of COVID-19 is that pandemic refuges are politically and epidemiologically viable, at least under certain epidemiological parameters. Multiple political jurisdictions have aimed to be refuges during the COVID-19 pandemic and have been successful at doing so. Pandemic refuges are a risk management policy concept worthy of serious consideration alongside other public health measures such as Vaccines and physical distancing.

The viability of pandemic refuges is further notable given the eccentricities of the broader literature on GCR refuges, such as in proposals for refuges underground, underwater, or in outer space. If pandemic refuges are viable, perhaps more exotic refuge concepts are too. Alternatively, perhaps pandemic refuges are only viable because of their more conventional nature, involving basic protection of a population via activities that only begin after the start of the pandemic. It was certainly not the case that China or Western Australia (for example) were isolated from the rest of the world prior to the start of COVID-19. Therefore, the evidence from COVID-19 provides at most only limited support for the viability of GCR refuges more generally.

The COVID-19 evidence provides guidance on the types of places that are likely to be successful pandemic refuges. Island nations are emphasized in prior literature (Boyd & Wilson 2019; 2021), but these are not the only viable candidates. Indeed, China has succeeded despite having the world's longest land border and despite being the location where the pandemic originated; Western Australia has succeeded despite not being a nation and despite having a land border with other parts of Australia.

China and Western Australia are quite different in several respects. China is authoritarian, collectivist, and heavily populated in the most populous region of the world. Western Australia is democratic, individualist, and sparsely populated in one of the most remote regions of the world; Perth is, by some counts, the most remote big city in the world (Gill 2015).

Nonetheless, China and Western Australia are similar in some important ways. Both have a high degree of centralization and a high capacity for self-isolation: China via its authoritarian government and Western Australia via its social isolation and strong economy driven by a booming mining industry. Both also have a strong in-group cohesion. During the pandemic, both have also had a high motivation for avoiding pathogen spread.

Both China and Western Australia have also maintained extensive trade with outside places throughout the pandemic. They therefore classify as “open” refuges. Rigorous quarantine measures have helped to avoid importing the pathogen. This is encouraging because it suggests that pandemic refuges can provide a high degree of economic support for outside populations during pandemics, an important element for achieving the global objective of refuges—the continuity of civilization.

4.2 COVID-19 Vs. More Severe Pandemics

For as bad as COVID-19 has been, it is not the worst-case scenario. The case fatality rate has been low compared to some other pathogens. Supply chains have faced relatively minor disruptions. The continuity of civilization has not been under significant threat. The COVID-19 pandemic is not over yet, and it could still take a turn for the worse. Nonetheless, at its current trajectory, it is a significantly more mild event than the extreme global catastrophe scenarios that refuges are commonly proposed for. Insights from COVID-19 must be interpreted accordingly.

The feasibility of maintaining a pandemic refuge can be described in terms of two primary attributes of pathogens: infectivity and virulence. Infectivity is how readily the pathogen infects

additional hosts. Virulence is how much medical harm the pathogen causes in hosts. High infectivity makes it more difficult to maintain a pandemic refuge because it is easier for an initial case to cause an outbreak and more difficult to suppress any outbreaks that occur. High virulence may make it easier to maintain a refuge because the refuge population would tend to be more motivated to avoid exposure to the pathogen. Indeed, motivation for maintaining refuges during COVID-19 has waned as the distribution of vaccines has reduced the pathogen's virulence and thus reduced the overall disease burden in highly vaccinated populations. Alternatively, high virulence (especially if combined with high infectivity) could make it harder to maintain a refuge if enough of the personnel needed to maintain the refuge are incapacitated by the pathogen, though this would only apply to refuges where there has been some pathogen spread.

SARS-CoV-2, the pathogen driving COVID-19, has several characteristics previously identified as being likely characteristics of pathogens driving more extreme global catastrophic biological risks. Specifically, SARS-CoV-2 is an RNA virus; it spreads efficiently from human to human via respiratory processes; and it can spread before symptoms arise and during mild symptoms (Adalja et al. 2018). These characteristics mainly pertain to infectivity. SARS-CoV-2 is indeed a highly infectious pathogen. China, Western Australia, and other locales have only persisted as refuges via considerable effort and sacrifice. In more extreme pandemic scenarios, the pathogen would not necessarily be more infectious than SARS-CoV-2, though higher infectivity is possible. The Omicron variant of SARS-CoV-2, which is significantly more infectious than prior versions of the pathogen, will provide a valuable test for any jurisdiction attempting to remain a refuge.

More extreme pandemic pathogens are likely to be significantly more virulent than SARS-CoV-2. Indeed, some other known pathogens are more virulent. At the time of this writing, SARS-CoV-2 has a case fatality rate of 1.9%.²⁰ The same statistic was 11% for SARS-CoV-1 in the 2003 SARS outbreak (Chan-Yeung & Xu 2003). For H5N1 influenza, the World Health Organization has posited a case fatality rate of 60%, though Li et al. (2008) estimate it to be in the range of 14-33%. For smallpox, Gani and Leach (2001) estimate a case fatality rate of 15%. For Ebola, Lefebvre et al. (2014) estimate a case fatality rate of 65% for cases predominantly in Africa; Uyeki et al. (2016) report a rate of 19% for the US and Europe. New pathogens could potentially be even more virulent, including pathogens produced via biotechnology. Clearly, there is potential for pandemics with higher virulence than SARS-CoV-2.²¹ The higher virulence could increase the motivation for maintaining refuges.

Higher virulence would additionally increase the value of refuges. During COVID-19, refuges have provided value by enabling their inhabitants to have relatively normal lives (e.g., limited social distancing) while being safe from the pandemic. During a more extreme pandemic, refuges could have additional value by supporting the continuity of civilization, the recovery of civilization in the event of collapse, or the survival of the human species. Support for civilization suggests particular value for relatively large and economically advanced refuges in the model of the COVID-19 refuge of China.

There is no guarantee that refuges would succeed during more extreme pandemics. Refuge success depends on social and epidemiological factors that are not readily predicted. Nonetheless, the success of refuges during COVID-19 is encouraging, especially for the viability of maintaining open refuges during a pandemic with a highly infectious pathogen. Higher virulence in more extreme pandemics would further motivate populations to maintain refuges, though it could also interfere with operations in some pandemics. The new pandemic pathogen may need to be significantly more infectious than SARS-CoV-2—itsself already an unusually infectious pathogen—for refuges to not be a viable option.

²⁰ COVID-19 Dashboard, Center for Systems Science and Engineering, Johns Hopkins University, 26 December 2021, <https://gisanddata.maps.arcgis.com/apps/dashboards/bda7594740fd40299423467b48e9ecf6>

²¹ Virulence involves more than just the fatality rate; it also includes non-fatal medical harm. Social disruptions also factor into the total severity of a pandemic (Schoch-Spana et al. 2017).

5. Conclusion

Two years of the COVID-19 pandemic demonstrate the viability of refuges as a means of protecting populations from the pandemic. The strategy of jurisdictional isolation to be a refuge has been successful in maintaining low case rates and fatalities as compared to non-refuge areas. Prior literature has emphasized island nations as pandemic refuges, and some island nations have indeed performed well during COVID-19. This paper shows that other jurisdictions can also succeed, including non-island nations and subnational jurisdictions. Successful refuges can also vary in other ways including political system, geographic isolation, culture, and population density.

Future research should consider evidence from subsequent portions of the COVID-19 pandemic. How refuges handle Omicron and any major new variants may be especially telling. Research could also study a wider range of jurisdictions or dive deeper into specific refuge decisions. For example, quantitative research could explore statistical correlates of global refuge performance; qualitative research could explore how the attitudes and motivations of local publics and political leaders shaped refuge performance. Further research could also compare refuge performance during COVID-19 to more severe future pandemics and could further assess the value of pre-pandemic and during-pandemic refuge policy for improving refuge performance, drawing on the preliminary analysis presented in this paper and in Boyd and Wilson (2019; 2021) and Boyd et al. (2020). Policy analysis could also assess the role of pandemic refuges within broader portfolios of options for reducing pandemic risk and other GCRs, including the relation between refuges for pandemics and other global catastrophe scenarios. For example, rapid action to eradicate emerging pathogens may be of particular value (Thompson et al. 2021a) and would preclude the need for refuges. COVID-19 has shown pandemic refuges to be a viable risk management option; now there is a need to refine and advance policy recommendations. Given the possibility of more extreme future pandemics and the ethical importance of global catastrophic risk, this is important work to pursue.

6. Postscript: January-April 2022

Primary research for this manuscript was completed in January 2022. This postscript was written in April 2022 during the revise-and-resubmit stage. It discusses significant recent developments. The fact that there have been significant new developments during January-April 2022 underscores the dynamic nature of the pandemic and the need for future research analyzing future events.

Western Australia ended its refuge policy on 2 March 2022 (Ho et al. 2022). COVID-19 case numbers began rising in Western Australia shortly before then, driven by a slight relaxation of its border policy in February 2022 combined with the difficulty of suppressing the spread of the highly infectious Omicron variant (AMA 2022). Avoiding the spread of Omicron would have required Western Australia to maintain an even higher degree of isolation from the outside world, which would entail significant costs. At the same time, the benefits of avoiding pathogen spread had significantly diminished due to extensive vaccination. Therefore, Western Australia judged that the benefits of isolation no longer outweighed the costs (ibid.). Western Australia's refuge policy can be interpreted as a success in the sense that it maintained near-zero pathogen spread until the state was prepared to handle the spread and long after it was clear that the pandemic would not constitute an extreme global catastrophe. Prior research has found synergies between vaccines and non-pharmaceutical interventions such as refuges for the control of infectious diseases (Thompson et al. 2021b). Western Australia's experience in COVID-19 demonstrates the value of this approach. Western Australia's experience also raises the idea of refuge endgame, meaning the strategies for how refuges may go about ending their refuge status, and how that relates to broader risk management objectives. Further research could consider the theme of refuge endgame in more detail.

The story in China is different. China continues to pursue a refuge policy and is struggling to do so. Hong Kong suffered from a major surge in cases resulting in high fatalities (Smith et al. 2022).

Shanghai is currently experiencing a surge in cases, which China is responding to via a lockdown so strict that it is creating food shortages (Liang 2022). The high infectivity of Omicron appears to be posing a major challenge for China's refuge policy. Its recent experience suggests that pandemic refuges may not be viable for pathogens as infectious as Omicron, perhaps unless a jurisdiction maintains a "closed" refuge with zero interaction with outside populations. In China's case, a closed refuge policy would cause major disruptions to the global economy, which China plays an important role in. Time will tell whether China will be willing or able to maintain its refuge policy under Omicron.

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