Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
The potential impact of vulnerability and coping capacity on the pandemic control of COVID-19

Dear Editor,

Worldwide, the coronavirus disease 2019 (COVID-19) has induced a substantial global burden. Since its first diagnosis in Wuhan, China, its spread has affected 216 countries.1 As of 16 May, 2020, there were more than 4.4 million cases and greater than 302,000 confirmed deaths among patients with COVID-19. Arguably, some nations with lower capacity to cope with the pandemic, especially in low and middle-income countries, might have poorer control of the disease. However, no previous study has proven this association. On the contrary, a recent study published in the Journal of Infection examined the association between country-specific global health security index (GHSI) and the burden of COVID-19, but the findings showed that countries with higher GHSI did not have higher COVID-19 rate and had greater number of COVID-19 cases and deaths.2 Hence, further exploration of the association between country capacity and COVID-19 burden is needed based on other indicators.

The Joint Research Centre (JRC) of European commission has developed an index for risk management named “INFORM”,3 which is a composite indicator based on risk concepts published in the literature. The INFORM model identifies countries at risk of disasters and crisis that could overwhelm response capacity for each country. It ranks countries based on their likelihood of requiring global assistance; synthesizes a risk profile for each country that demonstrates the degree of individual components at risk; and enables trend analysis.4 Two of its dimensions, namely vulnerability and lack of coping capacity, are particularly relevant to the COVID-19 pandemic. Vulnerability refers to the susceptibility of populations to hazardous incidents, and the lack of coping capacity represents inadequacy of resources that can alleviate the impact of pandemics. The vulnerability dimension could be further subdivided into socioeconomic factors (development and deprivation [50%], inequality [25%], and aid dependency [25%]) and vulnerable groups (uprooted people or other groups). It represents the economic, political and social features of the populations that can be destabilised in the event of a hazardous incident.5 The lack of coping capacity measures if a country is unable to cope with disasters through the government’s effort and existing infrastructure. It could be institutional (disaster risk reduction and governance) or infrastructure-related (communication, physical infrastructure, and access to health systems). We aimed to evaluate if countries with lower vulnerability and higher coping capacity were associated with better control of the COVID-19 pandemic, as measured by incidence and mortality outcomes.

We established a panel of experts consisting of epidemiologists, physicians, and public health professionals who were tasked to determine the outcomes used in this study based on literature review. After discussion the panel determined the following outcome variables: the maximum 14-day cumulative incidence rate per 100,000 population since the first case (22 January to 30 April, 2020); and the incidence and mortality per 100,000 population within 30 days since the first COVID-19 diagnosis and first COVID-19 related death, respectively, from the Johns Hopkins Centre for Systems Science and Engineering (CSSE).6 The variables tested for association with these outcomes included the COVID-19 vulnerability and the COVID-19 lack of coping capacity as of 2018. Three linear regression models were constructed for the three outcomes whilst adjusting for Gross Domestic Product (GDP) of the same year for each nation;7 and the population density of each country from the World Population Review.8 The study was approved by the Survey and Behavioral Research Ethics Committee of the Chinese University of Hong Kong (SBRE-19-592). All p values ≤0.05 were considered statistically significant.

The distribution of vulnerability and coping capacity scores was shown in Fig. 1. The COVID-19 vulnerability score was the highest in Italy (score 8.2 out of 10), Japan (8.2), Croatia (8.1) and Latvia (8.1). Countries with the severest lack of coping capacity included Central African Republic (9.4), Comoros (9.1), Equatorial Guinea (7.7), and Burundi (7.6). From multivariate regression analysis (Table 1), countries with higher vulnerability were significantly associated with higher maximum 14-day cumulative incidence since the first case (β coefficient 7.54, 95% CI. 2.82, 12.27, p=0.002), as well as the incidence (β coefficient 3.52, 95% CI. 0.94, 6.11, p=0.008) and mortality (β coefficient 0.50, 95% CI. 0.17, 0.84, p=0.003) per 100,000 population within 30 days since the first COVID-19 diagnosis and first COVID-19 related death, respectively. On the contrary, higher coping capacity was associated with lower maximum 14-day cumulative incidence (β coefficient -8.54, 95% CI. -12.41, -4.68, p<0.001), and lower incidence (β coefficient -3.09, 95% CI. -5.00, -1.18, p=0.002) and mortality (β coefficient -0.34, 95% CI. -0.64, -0.04, p=0.028) per 100,000 population within 30 days. There was no interaction or multicollinearity among the covariates.

Our findings imply that reducing vulnerability and enhancing capacity to cope could potentially mitigate the COVID-19 pandemic. Since the components of the two predictor variables are modifiable, countries that aim to increase their capability to combat the COVID-19 pandemics could make reference to the detailed subcategories under these two dimensions. The government could consider to take active steps in enhancing the resilience of the society and availability of measures that could protect the vulnerable population. Nevertheless, there are limitations of our study. Firstly, there may be other confounders that could not be controlled for, including personal behaviour and the stringency of Governmental policies,7 such as measures related to social distancing, school closure, supply of personal protective equipment (PPE), as well as...
Table 1
The association between vulnerability index, ability to cope score and the incidence/mortality outcomes related to COVID.

| (A) INFORM 2017 vulnerability index | (B) INFORM 2017 lack of coping capacity index |
|-------------------------------------|----------------------------------------------|
| Incidence outcome (A) | Mortality outcome (C) |
| $\beta$ coefficients | 95% CI | p | $\beta$ coefficients | 95% CI | p |
| COVID-19 Vulnerability index | 7.54 | 2.82 | 12.27 | 0.002 | 3.52 | 0.94 | 6.11 | 0.008 | 0.50 | 0.17 | 0.84 | 0.003 |
| COVID-19 Coping capacity | -8.54 | -12.41 | -4.68 | <0.001 | -3.09 | -5.00 | -1.18 | 0.002 | -0.34 | -0.64 | -0.04 | 0.028 |

The linear regression models were controlled for Gross Domestic Product (GDP) and population density. Incidence outcome (A): the maximum 14-day cumulative incidence rate per 100,000 population since the first case from 22 January to 30 April, 2020; Incidence outcome (B): the incidence per 100,000 population within 30 days since the first COVID-19 diagnosis; and Mortality outcome: (C) the mortality per 100,000 population within 30 days since the first COVID-19 related death.

(A). INFORM 2017 vulnerability index

(B). INFORM 2017 lack of coping capacity index

Fig. 1. The distribution of COVID-19 vulnerability index and COVID-19 lack of coping capacity index

Sources: Source of Figures: Marin-Ferrer M, Vernaccini L, Poljanssek, K. Index for Risk Management INFORM Concept and Methodology Report — Version 2017, EUR 28655 EN, doi:10.2760/094023

References
1. WHO. Coronavirus disease (COVID-19) outbreak situation. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019. Accessed on 10 May, 2020.
2. Artiklen T, Chin KL, Liew D, Ofori-Assenso R. Rethinking pandemic preparation: Global Health Security Index (GHSI) is predictive of COVID-19 burden, but in the opposite direction. J Infect 2020 May 8 S0163-4453(20)30273-5online ahead of print. doi:10.1016/j.jinf.2020.05.001.
3. Marin-Ferrer M, Vernaccini L, Poljanssek, K. Index for Risk Management INFORM Concept and Methodology Report — Version 2017, EUR 28655 EN, doi:10.2760/094023
4. The 2019 Novel Coronavirus COVID-19 (2019-nCoV) data repository by Johns Hopkins Centre for Systems Science and Engineering (CSSE). Available at: https://systems.jhu.edu/research/public-health/ncov/. Accessed on 10 May, 2020.
5. The Economist Intelligence Unit, World Bank and Central Intelligence Agency World Factbook. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/we.html. Accessed on 10 May, 2020.
6. Countries by density by population 2020. World Population Review. Available: https://worldpopulationreview.com/countries/countries-by-density/. Accessed on 27 April, 2020.
7. University of Oxford. Variation in Government responses to COVID-19. Available at: https://www.bsg.ox.ac.uk/research/publications/variation-government-responses-covid-19. Accessed on 08 May, 2020.
8. Prem K, Liu Y, Russell TW, Kucharski AJ, Eggo RM, Davies N et al. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. Lancet Public Health 2020;5:e261–70.
9. Pan A, Liu L, Wang C, Guo H, Hao X, Wang Q et al. Association of Public Health Interventions With the Epidemiology of the COVID-19 Outbreak in Wuhan, China. JAMA 2020 Apr 10. doi:10.1001/jama.2020.6130.

quarantine and containment strategies. In addition, the COVID-19 vulnerability used was developed in 2018, and we assumed that the index of each country did not change before the beginning of the pandemic in 2019. Also, we should emphasize that these are preliminary findings, and the cause-and-effect relationships are yet to be further examined by larger-scale studies.

In conclusion, we identified vulnerability and ability to cope as two important aspects in the face of an infectious disease pandemic, and they bear a potential impact to mitigate the COVID-19 pandemic. Future studies should evaluate the specific components of these indices that exert the greatest impact on pandemic control.

Declaration of Competing Interest
None declared

Acknowledgment
We are grateful for the technical assistance offered by Mr. Peter Choi of the School of Public Health and Primary Care, The Chinese University of Hong Kong

Funding
None
10. Anderson RM, Heesterbeek H, Klinkenberg D, Hollingsworth TD. How will country-based mitigation measures influence the course of the COVID-19 epidemic? Lancet 2020; 395:931–4.