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Global mortality benefits of COVID-19 action

Sunbin Yoo^{†,*}, Shunsuke Managi[†]

Urban Institute & School of Engineering, Kyushu University, Japan



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ABSTRACT

The rapid spread of COVID-19 motivated countries worldwide to mitigate mortality through actions including social distancing, home quarantine, school closures, and case isolation. We estimate the global mortality benefits of these actions. We use county-level data on COVID-19 from January 2020, project the number of mortalities until September 2020, and calculate the global mortality benefits using the age- and country-specific value of a statistical life (VSL). Implementing all four types of actions above would save approximately 40.76 trillion USD globally, with social distancing accounting for 55% of the benefits. The monetary benefit would be the largest in the US, Japan and China. Our findings indicate that global actions during COVID-19 have substantial economic benefits and must be implemented in response to COVID-19.

1. Introduction

1.1. Research motivation

COVID-19 is a global pandemic that has resulted in 1484,811 infected cases and 88,538 deaths as of April 9, 2020 (WHO), and researchers predict that global mortality will be massive, as in Ji et al. (2020) and Remuzzi et al. (2020). Countries worldwide have begun to implement actions to mitigate infections and deaths. These actions can be categorized into four types: social distancing, home quarantine, school closures, and case isolation.

However, whether these actions are effective in reducing the number of global cases and mortality remains unanswered, particularly from a global perspective. Investigating the global perspective is crucial, as it would enable countries to collaborate on the next pandemic, as mentioned in Chen (2020), Mendes (2020), Ceylan et al. (2020). In other words, questions remain regarding how these actions affect the total mortality damage of COVID-19 outside of China, the US, or the UK, which will be tremendous. Hence, to better design a set of policies that enables the reduction of cases and mortalities, this question must be addressed.

Thus, this study empirically examines the effectiveness of these actions for mitigating loss of mortality benefits, which is the monetized value of small changes in the number of mortalities aggregated to express the value related to one death in a population (Viscusi and Masterman, 2017). This is a crucial parameter for policy evaluation in the global context. We use county-level mortality data on COVID-19

from January 2020, project the number of mortalities until September 2020, and calculate the global mortality benefits, which is the monetized value of the decreased number of mortalities.

1.2. Theoretical framework

Our study contributes to two strands of literature. First, it contributes by examining the global monetized benefits of mortality during the COVID-19 pandemic. Because maintaining the lowest mortality possible should be the highest priority for all governments regardless of borders, our results are essential as they provide evidence that global actions during epidemics are essential because they provide substantial economic benefits that enable countries to mitigate inevitable economic downturns. However, we also find that previous works evaluating these actions mainly focused on the US, UK, and China. For example, previous works mentioned that these actions were effective in China in containing the number of mortalities and infected cases, as in Anderson et al. (2020), and reduced peak healthcare demand by 2/3 in the US and UK, as in Ferguson et al. (2020), which could save 7.9 trillion USD in the US (Greenstone and Nigam, 2020). Furthermore, Kraemer et al. (2020) argued that these actions could substantially reduce the number of mortalities in Wuhan, China. Thus, we contribute by incorporating countries other than the US, UK, and China and by providing global estimates and implications. In this sense, our study is closely related to that of Mandel and Veetil (2020), which analyzes the impact of lockdown on the world economy.

Second, our result contributes by calculating the value of lives.

* Corresponding author.

E-mail address: yoo.sunbin.277@m.kyushu-u.ac.jp (S. Yoo).

[†] These authors contributed equally to this work.

Previous research considers diverse perspectives on the impact of COVID-19 in various sectors: (Wang, M., & Flessa, S. (2020). It computes the spread of the disease and simulates the effects of interventions on health using dynamic system models. Govindan et al. (2020) examine how COVID-19 can affect healthcare supply systems. Fernandes (2020) investigates how the global economy is affected by comparing economic conditions during SARS and the 2008–2009 financial crisis. Nakamura and Managi (2020) calculate the overall relative risk of the importation and exportation of COVID-19 from every airport to local municipalities around the world. While it is also essential to recognize the impacts of COVID-19 on diverse sectors, the disease ultimately and closely affects people's lives. Thus, our essential contribution is that we offer an approach for computing quantitative estimates of the effects of various actions on the value of lives. Therefore, it is relatively easy to understand which actions are more effective in reducing the cases and mortalities.

The remainder of this paper is structured as follows. Section 1 provides background in terms of policy, and Section 2 presents the model and introduces the data used in this study. Section 3 shows the empirical results. Section 4 discusses practical implications, and Section 5 concludes.

2. Methodology

2.1. Scenario settings

We establish two scenarios before computing the number of mortalities and the global mortality benefits. First, we establish a scenario involving the most aggressive form of social distancing, with all four additional actions included (social distancing, home quarantine, closure of schools, and case isolation), as the Action Scenario. We establish another scenario, the Nonaction Scenario, which does not include any of the actions included in the Action Scenario and depends on a form of “herd immunity.” The Nonaction Scenario does not mean that a country is not taking any actions to mitigate mortalities. Instead, it refers to a hypothetical situation in which countries are not implementing the four actions above.¹ We assume that all measures started in late March and that COVID-19 will persist until late September. Then, we compare the projected number of mortalities and global mortality benefits of the two scenarios to draw implications on the monetized benefits of executing all four actions.

2.2. Empirical analysis

Computing the global mortality benefits starts with projecting the global number of mortalities. To do so, we refer to the transmission model and health care demand from Ferguson et al. (2020) and Greenstone and Nigam (2020) using basic reproduction numbers with country-level data. We develop a model that predicts the daily number of infected cases and mortalities under simple assumptions. First, we assume that the number of infected cases and mortalities follows the normal distribution, which approximates the growth curves for the epidemic. The center or peak of the distribution, for instance, would correspond to the peak of the daily number of new infected cases. Then, we compute the number of mortalities based on the number of projected infected cases and the infection fatality ratio (IFR) from Verity et al. (2020). To acquire the number of mortalities based on age group, we adjust for the age distribution of each country, referring to World Bank data. We determine nine age groups and their distributions for each country, and we adopt the same distribution for the total number of mortalities. Using the number of mortalities, we calculate

¹ Of course, it is possible to include actions other than the four mentioned in Section 2.1. Nevertheless, if none of the four actions mentioned in Section 2.1. is included, we classify the scenario as a Nonaction Scenario.

the reduction in mortality from the Nonaction Scenario to the Action Scenario and compute the global mortality benefit using age-varying and country-specific estimates of the value of a statistical life (VSL), referring to Greenstone and Nigam (2020), Viscusi and Masterman (2020), Jumbri et al. (2018), and Murphy and Topel (2006).²

Our model calculates direct deaths with a simple model structure instead of directly including intensive care unit (ICU) bed demand overflow. As a result of this simple structure and the many places that are currently replacing the ICU in practice globally, our model is applicable to discussions of important social aspects with a focus on the direct number of mortalities. Ferguson et al. (2020) and Greenstone and Nigam (2020) apply a more complex model by adopting the demand overflow of ICU beds, but this would require more assumptions, and the number of assumptions would increase if we broadened the research scope to include the entire world.

First, the demand for ICU beds is subject to change. For the Chinese data on ICUs, clinicians noted that only half of the patients seemed to need invasive mechanical ventilators; the others were given pressurized oxygen and may not have needed an ICU bed, as mentioned in Adam (2020). Furthermore, the demand for ICU beds is subject to change according to the efficiency of bed management in hospitals, as in Davie et al. (2005). Second, ICU beds are not available in low-income countries (i.e., Cambodia, Congo, Ethiopia, Kenya, Nepal, and Uganda). These low-income countries lack ICU beds, and more than 50% of these countries lack any published data on ICU capacity, as mentioned in (Murthy et al., 2015). Third, referring to Onuma et al. (2017), as the pandemic persists, countries increase their adaptation capability, which works globally to reduce adverse effects (i.e., mortalities) in general. Increased adaptation capability would reduce ICU bed demand, requiring more complex assumptions, whereas we focus on implications in the simple but global context. Therefore, in this study, we focus on the number of direct deaths and discuss global implications.

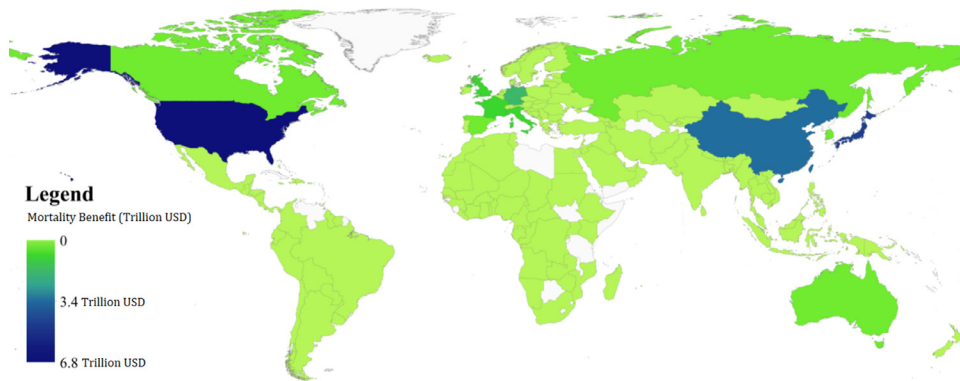
3. Results

Our calculated global mortality benefit shows that adopting the most aggressive form of action would save approximately USD 40.76 trillion globally. Considering that the global GDP in 2018 was approximately 85.91 trillion USD (World Bank), our results show a savings of approximately 47.44% of the GDP as a result of taking action. This result indicates that world populations are willing to pay USD 40.76 trillion for mortality risk reductions. Our results also show that social distancing has the most substantial effects of saving USD 14.79 trillion for mortality risk reductions, which is 17.22% of the global GDP.

Panel (A) in Fig. 1 shows the global distribution of global mortality benefits through a map. Our estimates suggest that the US would share the most benefit, approximately 17.71%, at the continent level. At the country level, Japan and China would benefit the most, as they share 12.64% and 11.96%, respectively, of the benefits of avoided damages worldwide. European countries also receive a large portion of the benefits: Germany has the highest savings, with 7.92%, followed by France (5.20%), the UK (5.00%), and Italy (4.37%). On the other hand, countries with the least benefits are mainly those on the African continent, for example, Gambia, Central African Republic, and Rwanda. Panel (B) in Fig. 1 indicates the global distribution of GDP loss due to nonaction. We calculate the GDP loss by calculating the global mortality benefit before the COVID-19 outbreak and then subtract it from the global mortality benefit after the COVID-19 outbreak. Then, we divide the difference between the two by the GDP. In Panel (A), our results indicate that the global average of GDP loss would be 35.61%.

² Greenstone's mortality benefit for the US is 7.9 trillion USD using US VSL; our estimates produce a mortality benefit of 7.22 trillion USD after adopting international VSL.

Panel (A)



Panel (B)

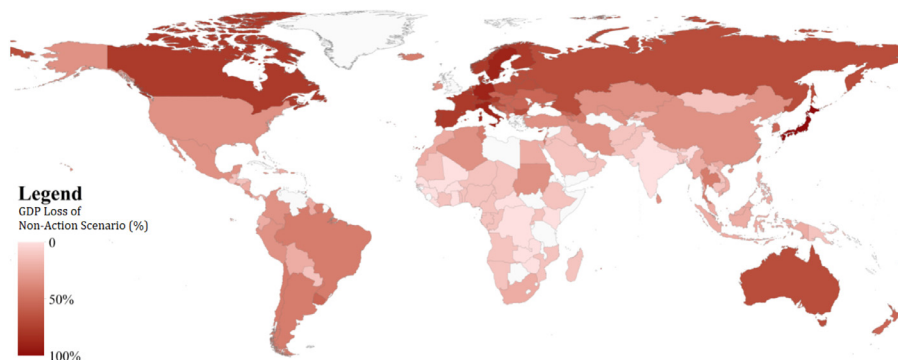


Fig. 1. Panel (A): Global Distribution of Global Mortality Benefits (in Trillion USD) A higher number (blue color) indicates that the benefits of actions (case isolation, home quarantine, school closure and social distancing) are high. Lower values (green colors) suggest that the estimated mortality benefit is lower. Panel (B): GDP Loss after COVID-19 in the Nonaction Scenario (%). A higher number indicates that the GDP loss is high. Lower values suggest that the estimated GDP loss is low.

Global loss due to nonaction was highest in Japan and European countries and low in African countries. One interesting finding here is that, while the US shows a relatively high global mortality benefit in Panel (A), our estimates suggest that the GDP loss after COVID-19 in the US would also be substantial (34.61%).

Fig. 2 shows the distribution of global mortality benefits by action. Among all types of actions, social distancing has the most significant benefits. Social distancing accounts for 55% of the benefit (USD 14.71 trillion), followed by home quarantine, school closures, and case

isolation, which account for 23% (USD 6.08 trillion), 21% (USD 5.59 trillion), and 2% (USD 0.49 trillion), respectively. Our findings are consistent with Ferguson and Greenstone, who show that the benefits of social distancing are substantial. However, this is not to say that other actions are a futile endeavor; given a choice between nonaction and action, countries worldwide would prefer to take action. Therefore, there is still a need to promote actions that yield lower benefits than social distancing.

Figs. 3, 4, and 5 show the portion of global benefits for national GDP

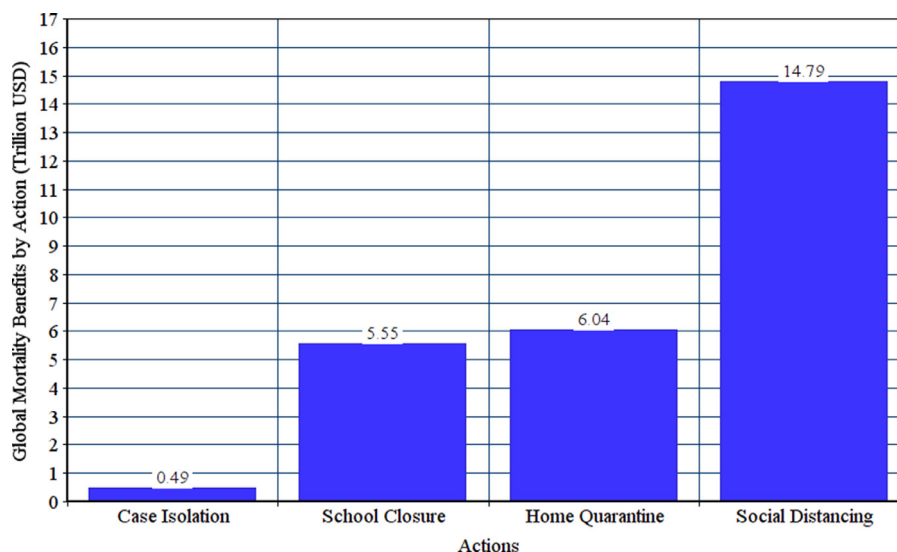
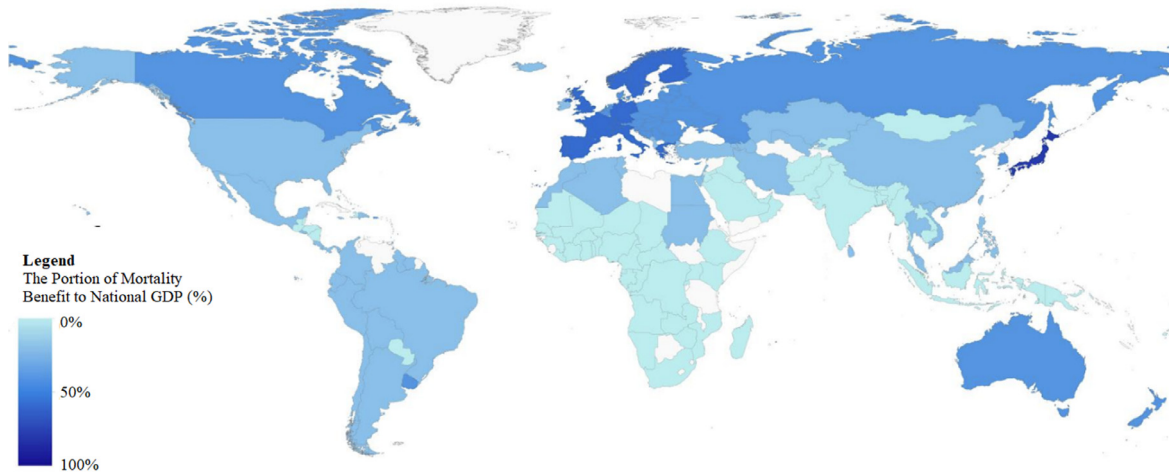
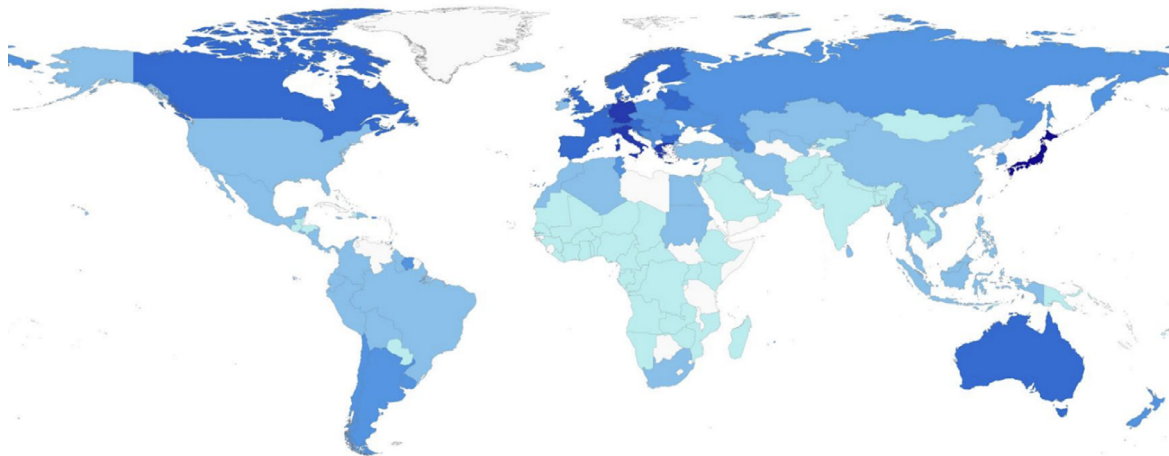


Fig. 2. Global Mortality Benefits by Action, expressed in trillion USD. The label on the bar graph refers to the monetized value of each action. For example, social distancing shows a global mortality benefit of 14.79 trillion USD.

Panel (A) Action Scenario 1



Panel (B) Action Scenario 2



Panel (3) Action Scenario 3

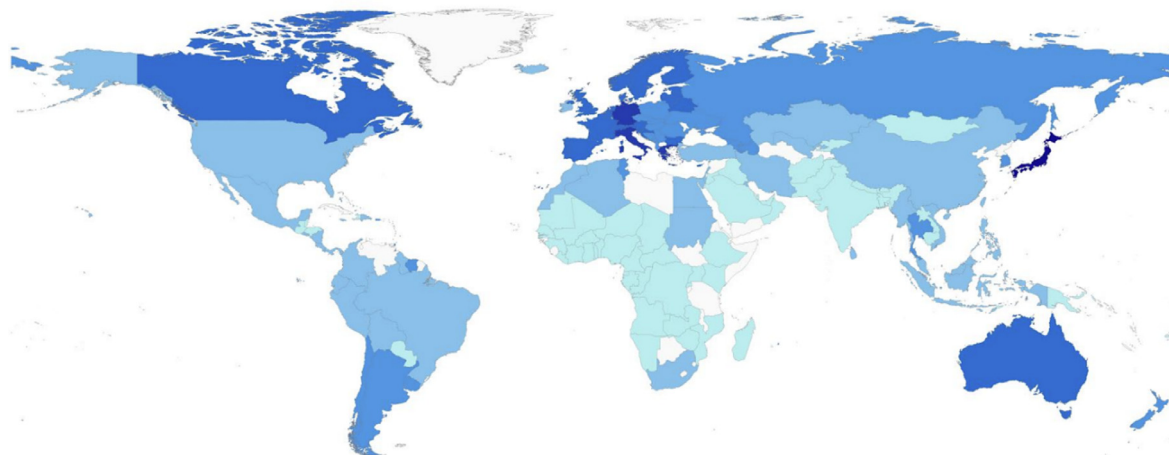


Fig. 3. The Portion of Global Benefits for National GDP by Country and Scenario, Expressed in Maps.

by country and scenario, expressed in maps; the projected number of mortalities by country and scenario; and the GDP loss of action scenarios, respectively. Panel (A) shows the result of Action Scenario 1, which includes case isolation, home quarantine, and social distancing; Panel (B) displays the result of Action Scenario 2, which includes school

closure, case isolation, and social distancing; Panel (C) presents the result of Action Scenario 3, which includes case isolation, school closure, home quarantine, and social distancing. We further provide the specific rankings for each figure in Appendix [Tables A1, A2 and A3](#).

Regarding age group, the 60- to 69-year-old age group would

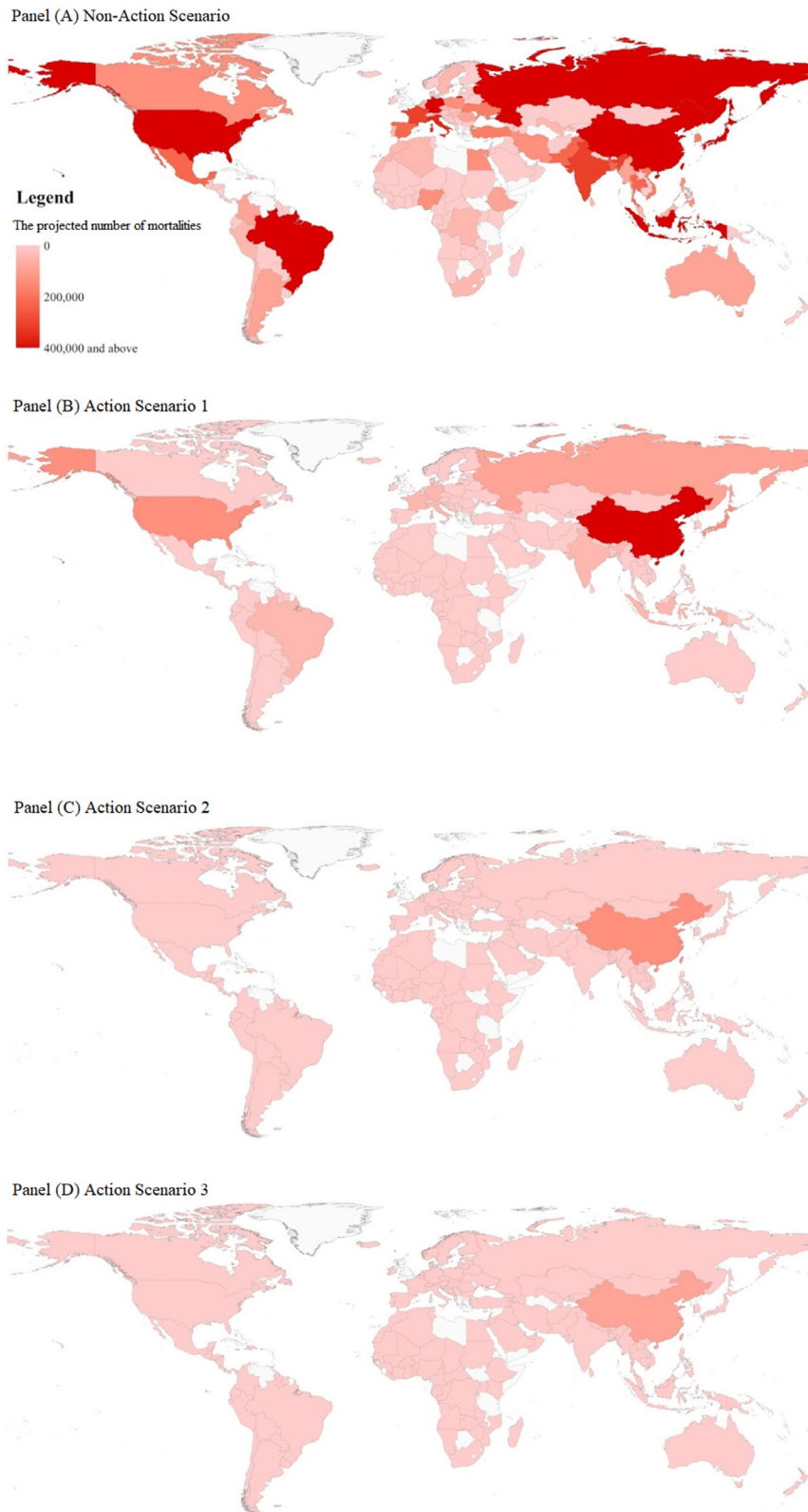


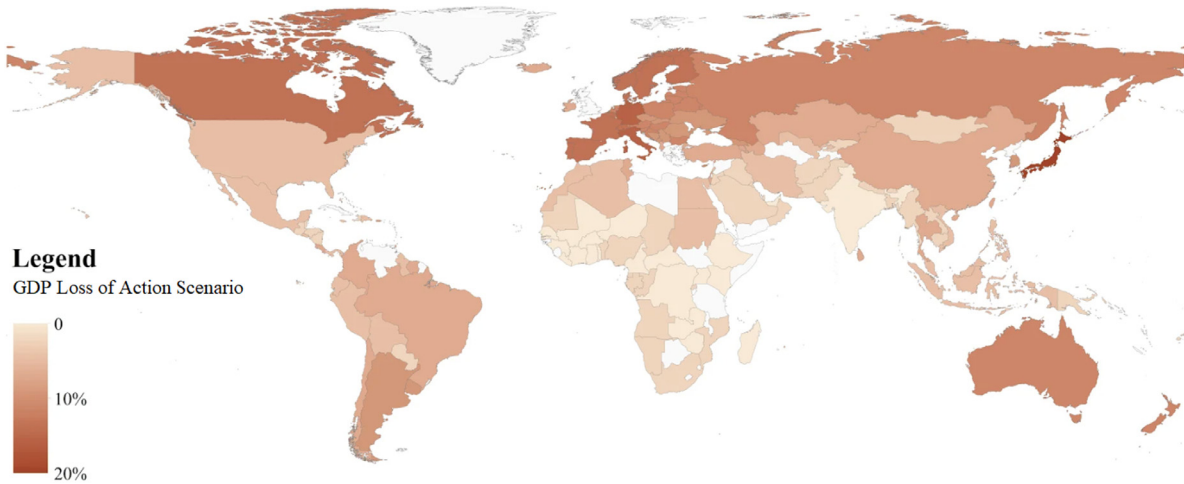
Fig. 4. The Projected Number of Mortalities by Country and Scenario, Expressed in Maps (Projected until Late September).

experience the most benefits, at 21.70%; the 50- to 59-year age group would experience 7.42%; and 40- to 49-year-olds would experience 1.92%. This result shows that the number of cases, the number of deaths and the willingness to pay to reduce risk to life are higher for the 60- to 69-year-old age group than for the other age groups.

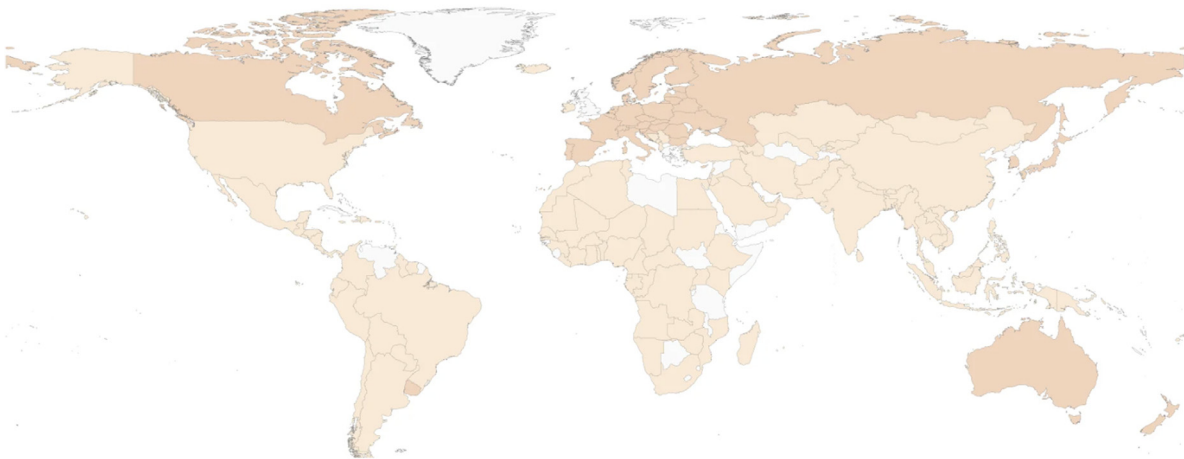
4. Discussion

The estimates for each country are worth highlighting. First, we find that the overall benefits are focused on developed countries. The top 10 countries with the greatest benefits include the US, Japan, China,

Panel (A) Action Scenario 1



Panel (B) Action Scenario 2



Panel (C) Action Scenario 3

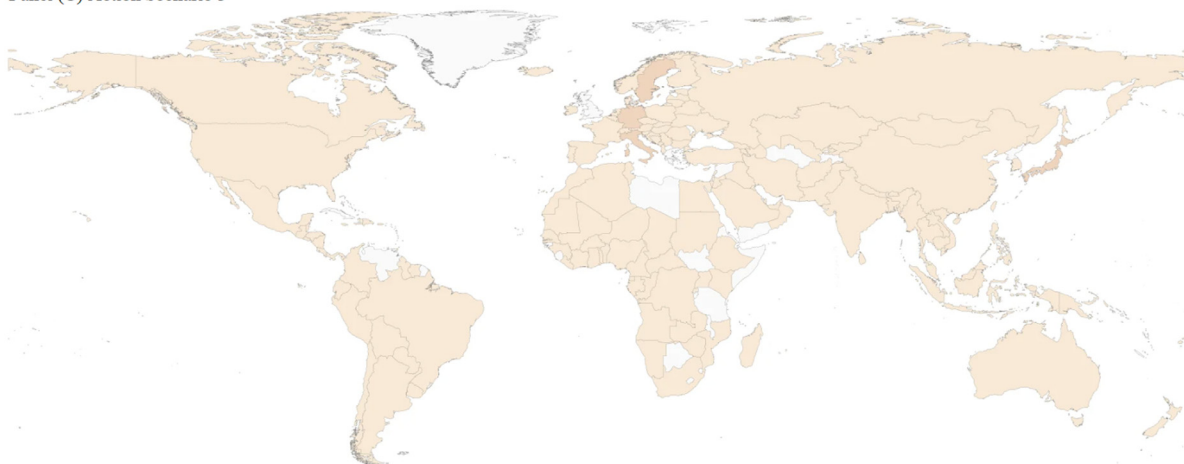


Fig. 5. The GDP Loss of Action Scenarios by Countries and Scenarios Expressed in Maps.

Germany, France, and the UK. The total global mortality of the top 3 countries (the US, Japan, and China) would be 16.78 trillion USD, which is more than 40% of the total global mortality benefits and accounts for approximately 20% of the global GDP for 2018. Such vast benefits cannot be easily derived from policy interventions, which

implies that the economic benefits of taking actions are substantial. This result also suggests that the people in these three countries value their lives and are therefore willing to pay a large amount of money to reduce risks.

Second, the bottom ten countries with the least benefits include

Table A1

Portion of Global Benefits to National GDP by Country and Scenario. (A): A list of the countries included in this study (alphabetical order). (B-a): The portion of benefits to the national GDP by country for Action Scenario 1, which includes case isolation, home quarantine, and social distancing. (B-b): The portion of benefits to the national GDP by country for Action Scenario 2, which includes school closure, case isolation, and social distancing. (B-c): The portion of benefits to the national GDP by country for Action Scenario 3, which includes case isolation, school closure, home quarantine, and social distancing.

(A) Countries	(B) Benefits from Actions (% to National GDP)		
	(B-a) Action Scenario 1	(B-b) Action Scenario 2	(B-c) Action Scenario 3
Afghanistan	11.40%	13.30%	13.40%
Albania	38.10%	44.20%	44.80%
Algeria	27.20%	31.60%	32.00%
Angola	10.60%	12.30%	12.40%
Antigua and Barbuda	27.90%	32.40%	32.80%
Argentina	39.20%	45.50%	46.00%
Armenia	37.60%	43.60%	44.20%
Australia	54.40%	63.10%	63.90%
Austria	58.40%	67.80%	68.60%
Azerbaijan	35.30%	41.00%	41.50%
Bahamas	17.10%	19.90%	20.10%
Bahrain	10.80%	12.50%	12.70%
Bangladesh	13.80%	16.10%	16.30%
Barbados	44.30%	51.40%	52.10%
Belarus	51.70%	60.00%	60.80%
Belgium	58.50%	67.90%	68.70%
Belize	16.40%	19.10%	19.30%
Benin	11.00%	12.80%	12.90%
Bhutan	15.90%	18.50%	18.70%
Bolivia	21.30%	24.70%	25.00%
Bosnia and Herzegovina	42.60%	49.50%	50.10%
Brazil	33.10%	38.40%	38.90%
Brunei Darussalam	24.20%	28.10%	28.50%
Bulgaria	52.60%	61.00%	61.70%
Burkina Faso	8.10%	9.50%	9.60%
Cambodia	11.90%	13.80%	13.90%
Cameroon	8.60%	10.00%	10.10%
Canada	59.20%	68.80%	69.60%
Central African Republic	7.10%	8.20%	8.30%
Chad	10.90%	12.60%	12.80%
Chile	35.60%	41.30%	41.80%
China	30.50%	35.40%	35.80%
Colombia	32.50%	37.70%	38.20%
Congo	12.50%	14.50%	14.70%
Costa Rica	30.00%	34.80%	35.30%
Côte d'Ivoire	8.60%	10.00%	10.10%
Croatia	56.80%	66.00%	66.80%
Cyprus	56.90%	66.10%	66.90%
Czech Republic	47.30%	54.90%	55.60%
Democratic Republic of the Congo	7.90%	9.20%	9.30%
Denmark	59.90%	69.50%	70.40%
Dominican Republic	20.10%	23.40%	23.70%
Ecuador	24.40%	28.30%	28.70%
Egypt	24.10%	28.00%	28.30%
El Salvador	27.90%	32.30%	32.70%
Equatorial Guinea	11.70%	13.60%	13.80%
Estonia	51.00%	59.20%	60.00%
Ethiopia	9.50%	11.00%	11.20%
Fiji	15.40%	17.90%	18.10%
Finland	64.10%	74.40%	75.30%
France	64.90%	75.40%	76.30%
Gabon	15.10%	17.50%	17.70%
Gambia	6.00%	7.00%	7.10%
Georgia	43.40%	50.30%	50.90%
Germany	69.60%	80.80%	81.80%
Ghana	8.20%	9.50%	9.60%
Greece	74.10%	86.00%	87.10%
Grenada	26.30%	30.50%	30.90%
Guatemala	13.80%	16.00%	16.20%
Guinea	5.50%	6.40%	6.50%
Guyana	20.20%	23.50%	23.80%
Haiti	16.50%	19.20%	19.40%
Honduras	16.20%	18.80%	19.00%

Table A1 (continued)

(A) Countries	(B) Benefits from Actions (% to National GDP)		
	(B-a) Action Scenario 1	(B-b) Action Scenario 2	(B-c) Action Scenario 3
Hungary	48.70%	56.50%	57.20%
Iceland	33.40%	38.80%	39.30%
India	2.50%	3.00%	3.00%
Indonesia	19.70%	22.80%	23.10%
Iran	27.00%	31.30%	31.70%
Iraq	12.10%	14.10%	14.20%
Ireland	30.60%	35.60%	36.00%
Israel	33.40%	38.80%	39.30%
Italy	72.80%	84.50%	85.50%
Jamaica	29.20%	33.80%	34.30%
Japan	88.20%	102.40%	103.70%
Jordan	16.40%	19.00%	19.20%
Kazakhstan	31.50%	36.60%	37.10%
Kenya	7.70%	8.90%	9.00%
Kuwait	19.20%	22.30%	22.60%
Kyrgyzstan	16.30%	18.90%	19.10%
Laos	10.40%	12.10%	12.30%
Latvia	55.20%	64.00%	64.80%
Lebanon	24.20%	28.10%	28.50%
Liberia	6.70%	7.80%	7.90%
Lithuania	52.60%	61.00%	61.80%
Luxembourg	31.80%	36.90%	37.40%
Madagascar	9.10%	10.50%	10.70%
Malaysia	22.70%	26.30%	26.60%
Maldives	9.80%	11.40%	11.60%
Mali	7.60%	8.80%	8.90%
Malta	53.00%	61.50%	62.20%
Mauritania	13.70%	15.90%	16.10%
Mauritius	34.70%	40.20%	40.70%
Mexico	26.30%	30.50%	30.90%
Mongolia	15.90%	18.50%	18.70%
Montenegro	39.90%	46.30%	46.80%
Morocco	23.60%	27.50%	27.80%
Mozambique	12.10%	14.10%	14.20%
Myanmar	18.80%	21.80%	22.10%
Namibia	11.60%	13.40%	13.60%
Nepal	13.70%	15.90%	16.10%
Netherlands	58.00%	67.30%	68.10%
New Zealand	49.60%	57.60%	58.30%
Nicaragua	19.20%	22.20%	22.50%
Niger	8.60%	10.00%	10.10%
Nigeria	13.90%	16.10%	16.30%
Norway	63.60%	73.90%	74.80%
Oman	11.90%	13.80%	13.90%
Pakistan	15.20%	17.60%	17.80%
Panama	22.40%	26.00%	26.30%
Papua New Guinea	10.70%	12.40%	12.50%
Paraguay	16.30%	18.90%	19.10%
Peru	25.70%	29.90%	30.20%
Philippines	22.10%	25.60%	25.90%
Poland	50.70%	58.80%	59.50%
Portugal	64.00%	74.30%	75.20%
Puerto Rico	40.60%	47.10%	47.70%
Qatar	12.50%	14.50%	14.60%
Republic of Korea	46.10%	53.50%	54.10%
Romania	46.30%	53.80%	54.40%
Russian Federation	50.10%	58.10%	58.80%
Rwanda	10.30%	12.00%	12.10%
Saint Lucia	23.60%	27.40%	27.80%
Saint Vincent and the Grenadines	29.50%	34.30%	34.70%
Saudi Arabia	14.90%	17.20%	17.50%
Senegal	7.10%	8.30%	8.40%
Serbia	43.30%	50.20%	50.80%
Seychelles	26.20%	30.40%	30.80%
Singapore	34.80%	40.40%	40.90%
Slovakia	46.30%	53.70%	54.40%
Slovenia	55.30%	64.20%	64.90%
South Africa	18.10%	21.00%	21.20%
Spain	62.60%	72.60%	73.50%
Sri Lanka	32.80%	38.10%	38.50%
Sudan	25.50%	29.60%	30.00%
Suriname	37.40%	43.40%	44.00%

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Table A1 (continued)

(A) Countries	(B) Benefits from Actions (% to National GDP)		
	(B-a) Action Scenario 1	(B-b) Action Scenario 2	(B-c) Action Scenario 3
Sweden	67.70%	78.60%	79.50%
Switzerland	63.80%	74.10%	75.00%
Thailand	34.00%	39.50%	40.00%
Timor Leste	16.00%	18.60%	18.80%
Togo	8.50%	9.90%	10.00%
Trinidad and Tobago	38.10%	44.30%	44.80%
Tunisia	34.50%	40.10%	40.60%
Turkey	31.80%	36.90%	37.30%
Uganda	8.40%	9.70%	9.80%
Ukraine	48.50%	56.30%	57.00%
United Arab Emirates	9.50%	11.10%	11.20%
United Kingdom	60.70%	70.50%	71.30%
United States of America	28.00%	32.50%	32.90%
Uruguay	45.30%	52.60%	53.20%
Uzbekistan	25.50%	29.60%	30.00%
Vietnam	22.10%	25.60%	25.90%
Zambia	8.10%	9.40%	9.50%
Zimbabwe	4.40%	5.10%	5.10%

Gambia, the Central African Republic, Liberia, Rwanda, and Togo (all less than 1%), which are mainly situated on the African continent. This result is due to the small number of cases in Africa until late March. It is questionable whether African countries have fewer cases than Europe or Asia because African countries do not have the medical capability to count confirmed cases. Because of the high volume of air traffic and trade between China and Africa, Africa is at high risk for the introduction and spread of COVID-19, as mentioned in [Nkengasong et al. \(2020\)](#). [Martinez-Alvarez et al. \(2020\)](#) mentioned that once the first cases were confirmed in West Africa, the increase in the number of confirmed cases of COVID-19 was rapid. However, [Wang et al. \(2020\)](#) and [Bukhari and Jameel \(2020\)](#) argue that Africa should be safer from COVID-19 because its high temperature and humidity can reduce the number of cases. If the virus that causes COVID-2019 is weakened by warm temperatures, then the environmental factors of countries with high temperatures and humidity can maximize the benefits of social distancing and can further prevent cases and deaths. However, other strands of research, including [Xie et al. \(2020\)](#) and [Breton \(2020\)](#), argue that temperature is not correlated with the sensitivity of COVID-19.

From a policy perspective, it is necessary to keep the public informed of the benefits of actions in terms of reducing cases and mortalities and maximizing global economic benefits. Actions, including social distancing, home quarantine, school closure and case isolation, are vital not only for global mortality benefits but also for preventing mortality and GDP loss. In this case, to maximize the benefits and mitigate cases and deaths, raising awareness of social distancing is required. Because this is a benefit-of-life value, which is challenging to monetize, there is room for our estimates to be increased if pandemics persist and people place more importance on the value of a life over this time, as in [Liu et al. \(2005\)](#).

In this sense, our estimates are not overestimated; they are likely to represent the lower bound and leave room to increase because we did not consider additional benefits derived from social distancing. For example, [Sen-Crowe et al. \(2020\)](#) argue that social distancing can slow infection and can further reduce cases and improve the quality of medical care for non-COVID-19 symptoms. Our results are not limited to social distancing and highlight the importance of other measures. Measures such as school closure or home quarantine could be more feasible than social distancing measures, as in [Fong et al. \(2020\)](#). Pandemic plans need to consider how to facilitate such efforts because multiple actions would maximize the benefits and save more lives worldwide.

Table A2

Projected Number of Mortality by Country and Scenario (Projected until Late September). (A): A list of the countries included in this study (alphabetical order). (B-a): The number of projected mortalities in the Nonaction scenario until late September. (B-b): The number of projected mortalities in Action Scenario 1, which includes case isolation, school closure, and social distancing. (B-c): The number of projected mortalities in Action Scenario 2, which includes school closure, case isolation, and social distancing. (B-d): The number of projected mortalities in Action Scenario 3, which includes case isolation, school closure, home quarantine, and social distancing.

(A) Countries	(B) Projected Number of Mortalities			
	(B-a) Nonaction	(B-b) Action Scenario 1	(B-c) Action Scenario 2	(B-d) Action Scenario 3
Afghanistan	25,353	4325	943	646
Albania	9423	1608	351	240
Algeria	67,963	11,595	2528	1732
Angola	18,650	3182	694	475
Antigua and Barbuda	238	41	9	6
Argentina	114,454	19,526	4258	2917
Armenia	8434	1439	314	215
Australia	90,968	15,519	3384	2319
Austria	39,271	6700	1461	1001
Azerbaijan	17,680	3016	658	451
Bahamas	718	122	27	18
Bahrain	1436	245	53	37
Bangladesh	222,920	38,030	8293	5682
Barbados	1101	188	41	28
Belarus	33,471	5710	1245	853
Belgium	50,242	8571	1869	1281
Belize	479	82	18	12
Benin	9448	1612	351	241
Bhutan	1148	196	43	29
Bolivia	20,024	3416	745	510
Bosnia and Herzegovina	12,899	2201	480	329
Brazil	446,933	76,247	16,626	11,392
Brunei Darussalam	606	103	23	15
Bulgaria	32,061	5470	1193	817
Burkina Faso	12,577	2146	468	321
Cambodia	19,059	3252	709	486
Cameroon	17,617	3006	655	449
Canada	149,584	25,519	5565	3813
Central African Republic	3311	565	123	84
Chad	9756	1664	363	249
Chile	52,720	8994	1961	1344
China	3666,538	625,511	136,395	93,460
Colombia	105,512	18,000	3925	2690
Congo	3884	663	144	99
Costa Rica	12,155	2074	452	310
Côte d'Ivoire	18,308	3123	681	467
Croatia	19,121	3262	711	487
Cyprus	3830	653	142	98
Czech Republic	44,795	7642	1666	1142
Democratic Republic of the Congo	63,435	10,822	2360	1617
Denmark	25,489	4348	948	650
Dominican Republic	19,333	3298	719	493
Ecuador	30,740	5244	1144	784
Egypt	126,645	21,606	4711	3228
El Salvador	12,901	2201	480	329
Equatorial Guinea	858	146	32	22
Estonia	5984	1021	223	153
Ethiopia	94,512	16,124	3516	2409
Fiji	1239	211	46	32
Finland	26,691	4554	993	680
France	311,641	53,166	11,593	7944
Gabon	1928	329	72	49
Gambia	1493	255	56	38
Georgia	12,844	2191	478	327
Germany	419,026	71,486	15,588	10,681
Ghana	25,223	4303	938	643
Greece	55,712	9504	2072	1420
Grenada	252	43	9	6
Guatemala	21,047	3591	783	536
Guinea	8957	1528	333	228

(continued on next page)

Table A2 (continued)

(A) Countries	(B) Projected Number of Mortalities			
	(B-a) Nonaction	(B-b) Action Scenario 1	(B-c) Action Scenario 2	(B-d) Action Scenario 3
Guyana	1342	229	50	34
Haiti	13,848	2362	515	353
Honduras	11,931	2035	444	304
Hungary	41,499	7080	1544	1058
Iceland	1208	206	45	31
India	308,140	52,569	11,463	7854
Indonesia	417,010	71,142	15,513	10,630
Iran	132,261	22,564	4920	3371
Iraq	32,632	5567	1214	832
Ireland	15,618	2664	581	398
Israel	24,261	4139	903	618
Italy	323,881	55,254	12,048	8256
Jamaica	6354	1084	236	162
Japan	791,482	135,027	29,443	20,175
Jordan	10,346	1765	385	264
Kazakhstan	34,781	5934	1294	887
Kenya	35,100	5988	1306	895
Kuwait	4494	767	167	115
Kyrgyzstan	7902	1348	294	201
Laos	7545	1287	281	192
Latvia	8879	1515	330	226
Lebanon	12,464	2126	464	318
Liberia	4050	691	151	103
Lithuania	13,174	2248	490	336
Luxembourg	2052	350	76	52
Madagascar	21,000	3583	781	535
Malaysia	53,815	9181	2002	1372
Maldives	528	90	20	13
Mali	11,902	2030	443	303
Malta	2257	385	84	58
Mauritania	3665	625	136	93
Mauritius	3529	602	131	90
Mexico	231,554	39,503	8614	5902
Mongolia	3763	642	140	96
Montenegro	2129	363	79	54
Morocco	64,494	11,003	2399	1644
Mozambique	20,997	3582	781	535
Myanmar	80,548	13,742	2996	2053
Namibia	2261	386	84	58
Nepal	38,071	6495	1416	970
Netherlands	75,977	12,962	2826	1937
New Zealand	17,789	3035	662	453
Nicaragua	9066	1547	337	231
Niger	14,348	2448	534	366
Nigeria	137,381	23,437	5111	3502
Norway	20,650	3523	768	526
Oman	3890	664	145	99
Pakistan	231,799	39,545	8623	5909
Panama	8577	1463	319	219
Papua New Guinea	7845	1338	292	200
Paraguay	11,021	1880	410	281
Peru	65,248	11,131	2427	1663
Philippines	143,944	24,557	5355	3669
Poland	155,862	26,590	5798	3973
Portugal	52,588	8972	1956	1340
Puerto Rico	14,894	2541	554	380
Qatar	1988	339	74	51
Republic of Korea	190,499	32,499	7087	4856
Romania	81,846	13,963	3045	2086
Russian Federation	507,695	86,613	18,886	12,941
Rwanda	9843	1679	366	251
Saint Lucia	433	74	16	11
Saint Vincent and the Grenadines	253	43	9	6
Saudi Arabia	34,737	5926	1292	885
Senegal	12,267	2093	456	313
Serbia	27,688	4724	1030	706
Seychelles	198	34	7	5
Singapore	17,034	2906	634	434
Slovakia	19,537	3333	727	498
Slovenia	9427	1608	351	240
South Africa	76,677	13,081	2852	1954
Spain	218,112	37,210	8114	5560

Table A2 (continued)

(A) Countries	(B) Projected Number of Mortalities			
	(B-a) Nonaction	(B-b) Action Scenario 1	(B-c) Action Scenario 2	(B-d) Action Scenario 3
Sri Lanka	53,721	9165	1998	1369
Sudan	37,994	6482	1413	968
Suriname	1005	172	37	26
Sweden	45,528	7767	1694	1161
Switzerland	37,248	6355	1386	949
Thailand	210,553	35,920	7833	5367
Timor Leste	1326	226	49	34
Togo	5890	1005	219	150
Trinidad and Tobago	3605	615	134	92
Tunisia	24,208	4130	901	617
Turkey	172,502	29,429	6417	4397
Uganda	23,034	3930	857	587
Ukraine	168,541	28,753	6270	4296
United Arab Emirates	6416	1095	239	164
United Kingdom	279,866	47,745	10,411	7134
United States of America	731,068	124,720	27,196	18,635
Uruguay	12,033	2053	448	307
Uzbekistan	41,694	7113	1551	1063
Vietnam	190,620	32,520	7091	4859
Zambia	10,107	1724	376	258
Zimbabwe	11,004	1877	409	280

Conclusion

The COVID-19 outbreak indicates the need to evaluate the actions that governments worldwide are implementing to mitigate the number of mortalities and cases. The impact of these actions on the worldwide economy is estimated to be substantial. Our estimates suggest that at least 40.76 trillion USD can be saved globally. Economic loss due to reduced demand and supply as a result of COVID-19 has been discussed, but we show that reducing the loss of humans would be more significant because the total saved loss would be approximately 47.28% of the global annual GDP. Social distancing accounts for more than half of the estimates and would save 14.49 trillion USD globally. This amount is larger than the Chinese GDP and equivalent to approximately 2/3 of the US GDP. Our results show that these actions can produce substantial benefits worldwide.

Unfortunately, predicting the global mortality benefits a few months after the outbreak of COVID-19 does include the problem of uncertainty. However, we believe this research will provide guidelines and insights for researchers and policymakers by providing humble policy advice. Estimating more robust estimates with more data and over a longer period would boost the numerical precision of this research and should be a focus of future research.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the *Technological Forecasting & Social Change*.

Authorship contributions

Category 1

Conception and design of study: Sunbin Yoo, Shunsuke Managi; acquisition of data: Sunbin Yoo, Shunsuke Managi; analysis and/or interpretation of data: Sunbin Yoo, Shunsuke Managi;

Category 2

Drafting the manuscript: Sunbin Yoo; revising the manuscript critically for important intellectual content: Sunbin Yoo, Shunsuke

Table A3

GDP Loss of Action Scenarios by Countries and Scenarios Expressed in Table. (A): A list of countries included in this study (alphabetical order). (B-a): The GDP loss from the Nonaction Scenario. (B-b): The GDP loss of Action Scenario 1, which includes case isolation, home quarantine, and social distancing. (B-c): The GDP loss of Action Scenario 2, which includes school closure, case isolation, and social distancing. (B-d): the GDP loss of Action Scenario 3, which includes case isolation, school closure, home quarantine, and social distancing.

(A) Countries	(B) GDP Loss (% of National GDP)			
	(B-a) Nonaction	(B-b) Action Scenario 1	(B-c) Action Scenario 2	(B-d) Action Scenario 3
Afghanistan	13.787%	2.350%	0.514%	0.351%
Albania	45.936%	7.836%	1.710%	1.172%
Algeria	32.807%	5.596%	1.220%	0.836%
Angola	12.726%	2.171%	0.473%	0.325%
Antigua and Barbuda	33.689%	5.747%	1.252%	0.859%
Argentina	47.221%	8.056%	1.756%	1.203%
Armenia	45.327%	7.733%	1.687%	1.156%
Australia	65.582%	11.190%	2.441%	1.672%
Austria	70.370%	12.005%	2.618%	1.794%
Azerbaijan	42.550%	7.258%	1.583%	1.084%
Bahamas	20.625%	3.519%	0.768%	0.526%
Bahrain	12.992%	2.217%	0.483%	0.331%
Bangladesh	16.690%	2.846%	0.620%	0.425%
Barbados	53.432%	9.116%	1.987%	1.361%
Belarus	62.342%	10.635%	2.320%	1.589%
Belgium	70.484%	12.024%	2.622%	1.797%
Belize	19.795%	3.377%	0.735%	0.503%
Benin	13.263%	2.262%	0.493%	0.338%
Bhutan	19.212%	3.277%	0.714%	0.489%
Bolivia	25.665%	4.379%	0.956%	0.654%
Bosnia and Herzegovina	51.383%	8.767%	1.912%	1.309%
Brazil	40.658%	6.936%	1.512%	1.036%
Brunei Darussalam	29.215%	4.984%	1.087%	0.744%
Bulgaria	63.361%	10.810%	2.358%	1.615%
Burkina Faso	9.825%	1.676%	0.365%	0.250%
Cambodia	14.306%	2.441%	0.532%	0.365%
Cameroon	10.368%	1.769%	0.385%	0.264%
Canada	71.421%	12.185%	2.658%	1.821%
Central African Republic	8.527%	1.454%	0.317%	0.218%
Chad	13.113%	2.235%	0.486%	0.333%
Chile	42.898%	7.318%	1.595%	1.093%
China	36.763%	6.272%	1.368%	0.937%
Colombia	39.158%	6.679%	1.457%	0.998%
Congo	15.108%	2.577%	0.562%	0.386%
Costa Rica	36.178%	6.172%	1.345%	0.921%
Côte d'Ivoire	10.415%	1.778%	0.388%	0.266%
Croatia	68.530%	11.691%	2.549%	1.747%
Cyprus	68.618%	11.708%	2.554%	1.751%
Czech Republic	57.020%	9.728%	2.120%	1.453%
Democratic Republic of the Congo	9.564%	1.631%	0.356%	0.244%
Denmark	72.198%	12.318%	2.687%	1.841%
Dominican Republic	24.286%	4.144%	0.904%	0.619%
Ecuador	29.427%	5.020%	1.094%	0.749%
Egypt	29.061%	4.958%	1.081%	0.740%
El Salvador	33.588%	5.732%	1.251%	0.858%
Equatorial Guinea	14.132%	2.410%	0.525%	0.359%
Estonia	61.522%	10.496%	2.289%	1.568%
Ethiopia	11.452%	1.954%	0.426%	0.292%
Fiji	18.610%	3.175%	0.692%	0.474%
Finland	77.256%	13.179%	2.873%	1.969%
France	78.273%	13.354%	2.911%	1.995%
Gabon	18.150%	3.097%	0.676%	0.466%
Gambia	7.245%	1.236%	0.270%	0.186%
Georgia	52.269%	8.918%	1.945%	1.332%
Germany	83.908%	14.314%	3.121%	2.138%
Ghana	9.831%	1.678%	0.366%	0.252%
Greece	89.341%	15.242%	3.324%	2.277%
Grenada	31.663%	5.402%	1.178%	0.808%
Guatemala	16.598%	2.832%	0.618%	0.423%
Guinea	6.670%	1.138%	0.249%	0.170%
Guyana	24.379%	4.159%	0.907%	0.622%
Haiti	19.951%	3.402%	0.742%	0.509%
Honduras	19.535%	3.333%	0.728%	0.499%

Table A3 (continued)

(A) Countries	(B) GDP Loss (% of National GDP)			
	(B-a) Nonaction	(B-b) Action Scenario 1	(B-c) Action Scenario 2	(B-d) Action Scenario 3
Hungary	58.702%	10.015%	2.184%	1.496%
Iceland	40.280%	6.872%	1.498%	1.027%
India	3.127%	0.533%	0.117%	0.080%
Indonesia	23.706%	4.044%	0.881%	0.603%
Iran	32.534%	5.550%	1.211%	0.831%
Iraq	14.598%	2.490%	0.544%	0.373%
Ireland	36.949%	6.304%	1.374%	0.941%
Israel	40.308%	6.877%	1.499%	1.028%
Italy	87.745%	14.969%	3.263%	2.236%
Jamaica	35.157%	5.998%	1.308%	0.896%
Japan	106.392%	18.150%	3.957%	2.711%
Jordan	19.748%	3.370%	0.734%	0.502%
Kazakhstan	38.039%	6.490%	1.416%	0.970%
Kenya	9.247%	1.578%	0.345%	0.237%
Kuwait	23.190%	3.956%	0.862%	0.592%
Kyrgyzstan	19.650%	3.352%	0.732%	0.500%
Laos	12.584%	2.147%	0.469%	0.322%
Latvia	66.508%	11.347%	2.475%	1.696%
Lebanon	29.199%	4.982%	1.088%	0.745%
Liberia	8.083%	1.379%	0.301%	0.206%
Lithuania	63.380%	10.812%	2.357%	1.615%
Luxembourg	38.362%	6.544%	1.426%	0.978%
Madagascar	10.940%	1.866%	0.406%	0.280%
Malaysia	27.315%	4.659%	1.015%	0.695%
Maldives	11.872%	2.026%	0.442%	0.303%
Mali	9.117%	1.556%	0.339%	0.232%
Malta	63.846%	10.893%	2.376%	1.628%
Mauritania	16.562%	2.825%	0.616%	0.423%
Mauritius	41.780%	7.127%	1.554%	1.065%
Mexico	31.717%	5.411%	1.181%	0.809%
Mongolia	19.201%	3.275%	0.716%	0.490%
Montenegro	48.062%	8.199%	1.788%	1.225%
Morocco	28.514%	4.864%	1.060%	0.728%
Mozambique	14.593%	2.489%	0.542%	0.370%
Myanmar	22.639%	3.863%	0.843%	0.579%
Namibia	13.931%	2.377%	0.520%	0.356%
Nepal	16.534%	2.820%	0.615%	0.422%
Netherlands	69.913%	11.927%	2.602%	1.783%
New Zealand	59.780%	10.199%	2.223%	1.524%
Nicaragua	23.104%	3.941%	0.860%	0.589%
Niger	10.385%	1.772%	0.386%	0.264%
Nigeria	16.821%	2.870%	0.626%	0.429%
Norway	76.721%	13.088%	2.854%	1.957%
Oman	14.295%	2.440%	0.532%	0.365%
Pakistan	18.299%	3.122%	0.680%	0.465%
Panama	26.965%	4.601%	1.004%	0.689%
Papua New Guinea	12.876%	2.196%	0.479%	0.328%
Paraguay	19.639%	3.351%	0.731%	0.501%
Peru	31.019%	5.293%	1.155%	0.791%
Philippines	26.605%	4.540%	0.991%	0.679%
Poland	61.086%	10.421%	2.272%	1.556%
Portugal	77.183%	13.168%	2.870%	1.968%
Puerto Rico	48.958%	8.353%	1.821%	1.248%
Qatar	15.025%	2.563%	0.558%	0.383%
Republic of Korea	55.566%	9.480%	2.067%	1.417%
Romania	55.837%	9.526%	2.077%	1.424%
Russian Federation	60.353%	10.296%	2.245%	1.539%
Rwanda	12.450%	2.124%	0.464%	0.318%
Saint Lucia	28.497%	4.861%	1.060%	0.726%
Saint Vincent and the Grenadines	35.610%	6.076%	1.325%	0.909%
Saudi Arabia	17.916%	3.058%	0.667%	0.458%
Senegal	8.614%	1.468%	0.320%	0.219%
Serbia	52.158%	8.898%	1.940%	1.329%
Seychelles	31.571%	5.387%	1.175%	0.804%
Singapore	41.928%	7.153%	1.560%	1.069%
Slovakia	55.778%	9.516%	2.075%	1.422%
Slovenia	66.649%	11.371%	2.479%	1.700%
South Africa	21.798%	3.719%	0.810%	0.556%
Spain	75.447%	12.871%	2.806%	1.924%
Sri Lanka	39.536%	6.745%	1.470%	1.007%
Sudan	30.755%	5.248%	1.146%	0.788%
Suriname	45.109%	7.697%	1.681%	1.152%

(continued on next page)

Table A3 (continued)

(A) Countries	(B) GDP Loss (% of National GDP)			
	(B-a) Nonaction	(B-b) Action Scenario 1	(B-c) Action Scenario 2	(B-d) Action Scenario 3
Sweden	81.599%	13.920%	3.036%	2.080%
Switzerland	76.923%	13.124%	2.861%	1.960%
Thailand	41.037%	7.002%	1.527%	1.047%
Timor Leste	19.297%	3.291%	0.717%	0.492%
Togo	10.248%	1.748%	0.381%	0.261%
Trinidad and Tobago	45.967%	7.842%	1.710%	1.172%
Tunisia	41.612%	7.098%	1.547%	1.061%
Turkey	38.306%	6.534%	1.425%	0.975%
Uganda	10.105%	1.722%	0.375%	0.257%
Ukraine	58.496%	9.979%	2.175%	1.492%
United Arab Emirates	11.495%	1.962%	0.429%	0.294%
United Kingdom	73.183%	12.485%	2.721%	1.865%
United States of America	34.365%	5.863%	1.277%	0.875%
Uruguay	54.630%	9.319%	2.032%	1.391%
Uzbekistan	30.747%	5.246%	1.145%	0.786%
Vietnam	26.600%	4.538%	0.990%	0.679%
Zambia	9.717%	1.660%	0.363%	0.249%
Zimbabwe	5.267%	0.898%	0.196%	0.135%

Managi;

Category 3

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Appendix

In this section, we provide the results tables for Figs. 3, 4 and 5. [Table A1.](#)
[Table A2](#)
[Table A3.](#)

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Sunbin Yoo Current Affiliation:

Urban Institute, School of Engineering, Kyushu University

Contact: yoo@globalenv.k.u-tokyo.ac.jp

yoo.sunbin.277@m.kyushu-u.ac.jp

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Shunsuke Managi is the Distinguished Professor of Technology and Policy & Director of Urban Institute at the Kyushu University, Japan. He is a lead author for the Intergovernmental Panel on Climate Change (IPCC), a coordinating lead author for the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), a director for Inclusive Wealth Report 2018 (IWR 2018), an editor of “Economics of Disasters and Climate Change”, “Environmental Economics and Policy Studies”, and “Resource and Energy Economics”. He is the co-chair the Scientific Committee of the 2018 World Congress of Environmental and Resource Economists. He was the recipient of a JSPS Prize.