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.

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Home Alone: Implications of COVID-19 for Mental Health

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ABSTRACT

Rationale: The outbreak of the 2019 novel coronavirus disease (COVID-19) has induced a considerable degree of fear, emotional stress and anxiety among individuals around the world.
Objective: The objective of this study is to evaluate the relationship between COVID-19 virus cases per 1000 residents and mental health outcomes of individuals across the globe.
Methods: Using plausibly exogenous variation in daily country-level reports of new COVID-19 cases across the world, this study employs an individual-by-day global data set to assess the association between virus outbreak intensity and short-term measures of mental health outcomes.
Results: Results indicate that females are 20.02% (95 % CI [6.65 %, 33.39 %]) more likely than males to find life depressing, suggesting that they may bear a much larger mental health burden than males during the COVID-19 pandemic. The association between the pandemic and mental health is more pronounced among individuals staying at home for the past week, who are 14.81 % (95 % CI [3.46 %, 26.16 %]) more likely to feel anxious and 11.17 % (95 % CI [2.13 %, 20.21 %]) more likely to experience emotional instability than their counterparts. The association between virus outbreak intensity and the likelihood of anxiety among individuals staying at home increases with household size, ranging from 11.73 % (95 % CI [-4.65 %, 28.11 %]) among individuals with 0–1 members in the household to 21.02 % (95 % CI [5.73 %, 36.31 %]) among those with 4–8 members in the household.
Conclusion: These short-run estimates of mental health damages associated with COVID-19 imply that welfare losses from pandemics among individuals are enormous across the globe.

1. Introduction

The outbreak of 2019 novel coronavirus disease (COVID-19) has affected millions of individuals across the globe, causing uncertainty and fear for the future. According to the World Health Organization (WHO), the disease has caused over 196 million confirmed cases and 4.2 million confirmed deaths in about 215 countries by July 30, 2021. As governments and individuals alter their actions to mitigate the spread of this disease, researchers claim that the virus outbreak will have severe short-term and long-term consequences for mental health and well-being (Galea et al., 2020; Pfefferbaum and North, 2020; Fiorillo and Gorwood, 2020). Outside the US, historical evidence suggests that the severe acute respiratory syndrome (SARS) epidemic is associated with post traumatic stress disorder, depression and disease-related anxiety (Mak et al., 2009; Bonanno et al., 2008). More recently, social distancing and self-isolation, two primary measures recommended to limit the spread of the COVID-19 outbreak, are reported to take a toll on mental health among individuals (Ammar et al., 2020).

The objective of this study is to employ publicly available individual-level cross-sectional data from a large-scale survey covering respondents from 151 countries for the period between March 20, 2020, and April 16, 2020, to evaluate the relationship between COVID-19 virus outbreak intensity and different mental health outcomes. Using plausibly exogenous variation in daily country-level reports of new COVID-19 cases across the world, this study employs an individual-by-day global data set to assess the association between virus outbreak intensity and short-term measures of mental health outcomes. These measures include: whether an individual is anxious and easily upset, whether an individual is emotionally unstable and whether an individual has been bothered by feeling down, depressed, or hopeless over the past two weeks. The

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empirical specification consists of a suite of fixed effects at different levels to isolate the effect of the pandemic from potentially confounding factors that might influence mental health outcomes, such as daily variation in temperature, different intensities of social distancing policies across countries and time-varying physical and environmental conditions across regions. The model accounts for country fixed effects, day fixed effects, month-by-continent fixed effects and demographic characteristics to control for both time-invariant and time-varying unobservable determinants of mental well-being. More specifically, this study aims to generate short-run estimates of mental health damages associated with COVID-19 and contributes to quantifying the social cost of pandemics across the globe.

This article contributes to a growing literature on how the ongoing COVID-19 pandemic may have detrimental mental health consequences (Ueda et al., 2020; Haider et al., 2020). Past literature has shown a clear linkage between deteriorating mental health and the outbreak of infectious diseases such as the SARS epidemic (Jeong et al., 2016; Lau et al., 2005). Relatedly, there is an influx of studies from China reporting an increase in anxiety, depression, and posttraumatic stress symptoms in response to the COVID-19 outbreak (Ahmed et al., 2020; Cao et al., 2020; Wang et al., 2020). On a global scale, Fetzer et al. (2020) conduct a large-scale survey covering 58 countries and over 100,000 respondents between late March and early April 2020 to evaluate differences in beliefs and attitudes towards responses to the COVID-19 pandemic. They find that strong governmental responses are associated with negative mental health outcomes such as depression.

The study sheds light on different channels that may exacerbate the effect of the virus outbreak on individual mental health outcomes. The process of quarantine in response to the virus may result in economic distress, causing the incidence of psychological disorders (Brooks et al., 2020). There also exists mounting evidence on how COVID-19 may disproportionately affect different socioeconomic groups such as economically vulnerable populations and older individuals (Wang and Tang, 2020; Holmes et al., 2020). This is important because related literature on the economics of natural disasters shows that such negative exogenous shocks can reveal widening socioeconomic disparities across gender and other demographic categories (Neumayer and Plümper, 2007; Paudel and Ryu, 2018; Harman, 2016; Wenham et al., 2019; Paudel, 2021c; Shakya et al., 2021).

Finally, the study offers policy implications in relation to understanding the overall cost imposed by poor mental health outcomes on society. The study provides insights on which regions are more susceptible to adverse mental health outcomes associated with the virus outbreak. Empirical estimates from this study can be used to determine which regions to target, and identify timely and cost-effective policies for improved mental health services. As discussions on best ways to cope up with adverse mental health during the COVID-19 pandemic (Ammar et al., 2020; Chan et al., 2020) continue, figures from the study suggest that virus outbreaks may exacerbate mental health outcomes and impose large economic damages. Policymakers, interested in making decisions about the allocation of mental health treatment and research resources, can benefit from short-run estimates of associations between virus outbreak intensity and mental health outcomes across the globe.

The remainder of the article is structured as follows. Section 2 presents a brief literature review on the COVID-19 pandemic and discusses the data. Section 3 describes the empirical strategy employed in the study. Section 4 presents the empirical findings. Section 5 discusses economic implications of the main findings and Section 6 concludes.

2. Background and data

2.1. COVID-19, mental health and gender

Recent literature has explored different channels that may explain the association between the ongoing COVID-19 pandemic and poor mental health outcomes. According to Rajkumar (2020), symptoms of anxiety, depression and stress possibly associated with disturbed sleep are common psychological reactions to the pandemic. Cullen et al. (2020) claim that even individuals who have no pre-existing mental health conditions are expected to experience a significant increase in anxiety and depression-related symptoms, including post-traumatic stress disorder in some cases. There exists well-documented evidence that a change in emotional well-being seems to be more pronounced during the rise of disease outbreaks associated with unknown causes or rampant rumors (Ren et al., 2020; Cheng and Cheung, 2005). As the uncertainty associated with pandemics magnifies, individuals and communities tend to feel hopelessness, despair, grief, bereavement, and a loss of purpose (Usher et al., 2020; Huremovic', 2019). Importantly, individuals during the pandemic are also likely to experience "boredom, disappointment, and irritability under the isolation measures" (Li et al., 2020). Economic recession, in the aftermath of the pandemic, can worsen existing mental health problems as well (Golberstein et al., 2020). Specifically, financial insecurity and perceived fear of potential job loss during the pandemic contribute to psychiatric morbidity (Purtle, 2020).

The unique feature of the pandemic is that mass home-confinement directives such as stay-at-home orders, social isolation, and quarantine have been relatively new to the majority of the younger generation. For example, Pfefferbaum and North (2020) report that home confinement for indefinite periods and conflicting messages from the government and public health authorities intensify emotional distress among individuals around the world. Increased loneliness and reduced in-person interactions during the pandemic are primary risk factors for mental disorders such as schizophrenia, depression, and obsessive-compulsive disorders (Fiorillo and Gorwood, 2020). Extreme social media exposure and disparities in COVID-19 mortality rates are other channels that may contribute to elevated grief, depression, and anxiety among the general population (Gao et al., 2020; Purtle, 2020).

Differences in economic outcomes between males and females during the pandemic have received considerable attention in recent months. According to Sevilla and Smith (2020), women have been more likely than men to lose employment in response to the pandemic, causing them to specialize in caring activities. Relatedly, Collins et al. (2020) show that mothers with young children have reduced their work hours four to five times more than fathers. Although both men and women equally perceive the necessity of domestic tasks, men are likely to avoid such responsibilities and women are likely to perform additional unpaid chores (The'baud et al., 2019). Such circumstances are likely to affect work-life status and emotional well-being of females.

Social distancing measures also led to closures of schools and day-care centers, increasing child care needs among working mothers (Alon et al., 2020; Hupkau and Petrongolo, 2020). Competing demands from parenting, homeschooling and other caring duties (Pinho-Gomes et al., 2020) are likely to add additional stress among females. Women are more susceptible to short-term and long-term economic insecurity and emotional distress when facing hardships during the pandemic (Fortier, 2020). According to Oreffice and Quintana-Domeque (2020), poorer female employment outcomes during the economic crisis are also associated with a higher incidence of mental health issues. Women are more likely to be severely affected by the pandemic than men in well-being, job satisfaction, performance, and career progression (Milliken et al., 2020).

2.2. Methods

The core analysis of the study is based on (i) a large-scale survey covering 58 countries and over 100,000 respondents between late March and early April 2020 conducted by Fetzer et al. (2020) to study beliefs and attitudes towards multiple responses to the COVID-19 pandemic and (ii) global daily new COVID-19 cases assembled by the Johns Hopkins University Center for Systems Science and Engineering during the same time period (Dong et al., 2020).

2.2.1. Sampling and variable construction

Fetzer et al. (2020) launched a global online survey at the onset of the COVID-19 pandemic. According to Fetzer et al. (2020), this process started with the call for participation via social media on March 20th, 2020, producing nearly 1.4 million impressions on Twitter. Between March 20th and April 7th, 2020, 391,476 different users accessed the landing page, and more than 110,000 individuals from 175 countries eventually participated. Despite the global coverage of the sample, this sample should not be viewed as representative. It is plausible that the survey may have attracted participants that were more concerned about the COVID-19 pandemic than other citizens in their countries. Despite this limitation, it is worth pointing out that there exists no representative cross-country dataset covering mental health outcomes during the ongoing pandemic.

This study relies on three different questions to construct mental health-related outcomes. The first question, based on the Patient Health Questionnaire (PHQ) (Kroenke et al., 2001), asks respondents whether they have been bothered by feeling down, depressed or hopeless over the past two weeks. Their responses are collected on a 4-point scale: not at all (1), several days (2), more than half the days (3), and nearly every day (4). The binary indicator of depression used in this study takes a value of 1 if an individual has been bothered by feeling down, depressed or hopeless at least more than half the days over the past two weeks and 0 otherwise.

The responses to the last two questions, based on the Big-Five personality questionnaire (Gosling et al., 2003), are collected on a 7 point scale: disagree strongly (1), disagree moderately (2), disagree a little (3), neither agree nor disagree (4), agree a little (5), agree moderately (6) and agree strongly (7). The second question asks respondents if they see themselves as anxious and easily upset. The binary indicator of anxiety used in this study takes a value of 1 if an individual agrees to some extent that he/she is anxious and easily upset and 0 otherwise. The third question asks respondents if they see themselves as calm and emotionally stable. The binary indicator of emotional instability used in this study takes a value of 1 if an individual disagrees that he/she is calm and emotionally stable and 0 otherwise.

To explore behavioral changes in response to the COVID-19 pandemic, this study relies on two specific questions. These questions ask respondents to describe their behavior for the past week on a continuous scale of 0–100, where the minimum value of 0 indicates that the question does not apply at all and the maximum value of 100 indicates that it applies very much. Specifically, respondents describe (i) to what extent they stayed at home for the past week and (ii) to what extent they did not attend social gatherings for the past week. The binary indicator of staying at home used in this study takes a value of 1 if an individual states with a response of 100 that he/she stayed at home for the past week and 0 otherwise. The binary indicator of no social gathering takes a value of 1 if an individual states with a response of 100 that he/she did not attend social gatherings for the past week.

2.2.2. Summary statistics

The study employs an individual-by-day global data set to determine the association between COVID-19 virus outbreak intensity and short-term measures of mental health outcomes. Respondents from Africa, Americas, Asia, Europe and Oceania comprise 1.53 %, 34.19 %, 9.78 %, 53.10 %, and 1.40 % of the data, respectively. Table 1 breaks down the number of individuals, countries, and cases per 1 thousand people on a given day, with average rates of anxiety, emotional instability, and depression, along with their respective standard deviations. For example, the sample on March 20, 2020 consists of 1898 respondents from 58 countries with an average number of 0.156 COVID-19 virus cases per 1000 people. The first row of Table 1 shows that respondents are 42.2 % likely to feel anxious, 18 % likely to feel emotionally unstable and 16.4 % likely to find life depressing on March 20, 2020.

Table 2 provides a summary of variables used in the empirical model from March 20, 2020, to April 16, 2020. The average number of virus cases reported per 1 thousand people in a given day is 0.216, with a standard deviation of 0.339 and a maximum value of 5.44. The average number of virus cases per 1 thousand people ranges from 0.09 to 2.08 in countries such as Canada, US, Spain, Finland, Iran, China, Australia, Turkey and Saudi Arabia. Among three indicators of mental well-being, individuals in the sample are 40.4 % likely to feel anxiety, 18.3 % likely

Table 1
Summary statistics of COVID-19 cases and mental health outcomes in the study.

Number				Mean				Standard Deviation			
Month	Day	Individuals	Countries	Cases	Anxious	Unstable	Depressing	Cases	Anxious	Unstable	Depressing
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3	20	1898	58	0.156	0.422	0.180	0.164	0.230	0.494	0.384	0.370
3	21	14140	113	0.128	0.406	0.166	0.168	0.189	0.491	0.372	0.374
3	22	41582	134	0.178	0.420	0.190	0.174	0.267	0.494	0.393	0.379
3	23	14647	119	0.154	0.406	0.185	0.160	0.225	0.491	0.389	0.366
3	24	8543	112	0.192	0.413	0.203	0.165	0.288	0.492	0.403	0.371
3	25	3492	97	0.225	0.401	0.183	0.172	0.302	0.490	0.387	0.378
3	26	2772	91	0.191	0.424	0.184	0.146	0.293	0.494	0.387	0.354
3	27	2449	87	0.200	0.386	0.170	0.172	0.294	0.487	0.376	0.378
3	28	4288	91	0.272	0.371	0.176	0.143	0.336	0.483	0.381	0.351
3	29	4216	95	0.301	0.377	0.159	0.136	0.368	0.485	0.366	0.342
3	30	4233	96	0.319	0.391	0.176	0.184	0.347	0.488	0.381	0.387
3	31	2173	88	0.352	0.371	0.182	0.173	0.403	0.483	0.386	0.378
4	1	1489	81	0.476	0.309	0.156	0.137	0.504	0.462	0.363	0.344
4	2	1666	83	0.387	0.357	0.146	0.107	0.527	0.479	0.354	0.310
4	3	1219	63	0.354	0.306	0.182	0.144	0.542	0.461	0.386	0.352
4	4	731	60	0.505	0.341	0.161	0.192	0.636	0.474	0.368	0.394
4	5	580	47	0.520	0.360	0.193	0.141	0.655	0.481	0.395	0.349
4	6	534	59	0.661	0.358	0.172	0.174	0.737	0.480	0.378	0.380
4	7	395	51	0.819	0.392	0.139	0.175	0.668	0.489	0.347	0.380
4	8	467	47	0.545	0.471	0.270	0.244	0.630	0.500	0.444	0.430
4	9	294	39	0.593	0.415	0.201	0.204	0.661	0.494	0.401	0.404
4	10	213	41	0.810	0.418	0.225	0.230	0.810	0.494	0.419	0.422
4	11	145	36	0.664	0.414	0.214	0.186	0.702	0.494	0.411	0.391
4	12	160	34	1.025	0.369	0.219	0.175	0.885	0.484	0.415	0.381
4	13	186	37	1.477	0.392	0.199	0.156	1.405	0.490	0.400	0.364
4	14	163	36	1.279	0.380	0.239	0.147	0.927	0.487	0.428	0.355
4	15	125	30	1.220	0.304	0.120	0.160	0.846	0.462	0.326	0.368

Table 2
Summary statistics of key variables in the study.

Variables	Mean	Standard Deviation	Minimum	Maximum
	(1)	(2)	(3)	(4)
Virus cases (per 1000)	0.216	0.339	0	5.441579
Anxious = 1	0.404	0.491	0	1
Unstable = 1	0.183	0.387	0	1
Depressing = 1	0.166	0.372	0	1
Age	38.848	13.037	18	110
Household members	2.929	1.718	0	30
Income	1,468,180	44,500,000	0	10,000,000,000
Educations (Years)	16.353	4.676	0	25
Male = 1	0.436	0.496	0	1
Married = 1	0.563	0.496	0	1

to feel emotional instability and 16.6 % likely to feel depressed. In relation to demographic characteristics, individuals are on average 38.84 years old and reside in a household size of 2.9 people. The monthly household income before tax in a given country's currency is approximately 1.5 million units. The average years of education completed among respondents is 16.353 years. Finally, 43 % of the individuals in the sample are males and 56.3 % of them are currently married.

Fig. 1 through 3 show the geographical heterogeneity of average rates of anxiety, emotional instability and depression. In relation to individuals feeling anxious, rates are high in Canada, Brazil, Niger, Chad, Sudan, Kazakhstan and Mongolia (see Fig. 1). Average rates of emotional instability range at least 20 % among countries such as Brazil, Russia, Iran, Angola, Sudan and Indonesia (see Fig. 2). Finally, average rates of depression are high among individuals in Brazil, Algeria, Russia, Mongolia, Saudi Arabia, Turkey and Egypt (see Fig. 3). These figures highlight the geographical variation in the incidence of mental health-related issues in the aftermath of the COVID-19 pandemic.

3. Empirical strategy

To evaluate the association between COVID-19 and different measures of mental health, I estimate the equation below:

$$Y_{itc} = \beta_0 + \beta_1 Case_{tc} + \theta X_{itc} + \eta_t + \delta_c + \gamma_{mr} + E_{itc} \quad (1)$$

where Y_{itc} is a measure of mental health outcome for individual i recorded in day t of month m residing in continent r and country c. Mental health outcomes include: (i) whether an individual is anxious and easily upset, (ii) whether an individual is emotionally unstable and (iii) whether an individual has been bothered by feeling down, depressed, or hopeless over the past two weeks. $Case_{tc}$ gives the number of reported cases of COVID-19 per 1 thousand people during day t of a given month m in country c. To account for population size in each country, the study scales the number of virus cases per 1 thousand people. β_1 is the parameter of interest, which gives the change in probability of an individual experiencing a mental health outcome Y for every additional unit increase in reported virus cases per one thousand residents.

In the estimating equation above, X_{itc} represents a vector of individual-level demographics such as age, marital status, gender, household size, years of education and income. η_t denotes day-by-month fixed effects that indirectly control for unobservable determinants of mental health outcomes that may vary across days in a given country such as daily variation in temperature and change in policy shocks that possibly influence preexisting health conditions. Such policy shocks include variation in lockdown dates and availability of spots for testing facilities. This approach also accounts for changing economic circumstances within regions and across countries on a day-by-day basis. Including day-by-month fixed effects in the empirical specification accounts for time-varying unobservable determinants of mental health well-being at the day level.

δ_c denotes country fixed effects that account for geographical heterogeneity and unobserved time-invariant differences in characteristics across countries such as differential population densities, governmental effectiveness and the strength of economic institutions. For example, a country with a robust institutional framework may exhibit a lower risk of virus outbreak as well as greater access to mental health service facility. Under these circumstances, one needs to control for unobserved factors such as institutional characteristics when evaluating the association between virus outbreak intensity and mental health outcomes. γ_{mr} includes month-by-continent fixed effects, which account for any month-specific shocks such as poor macroeconomic conditions or

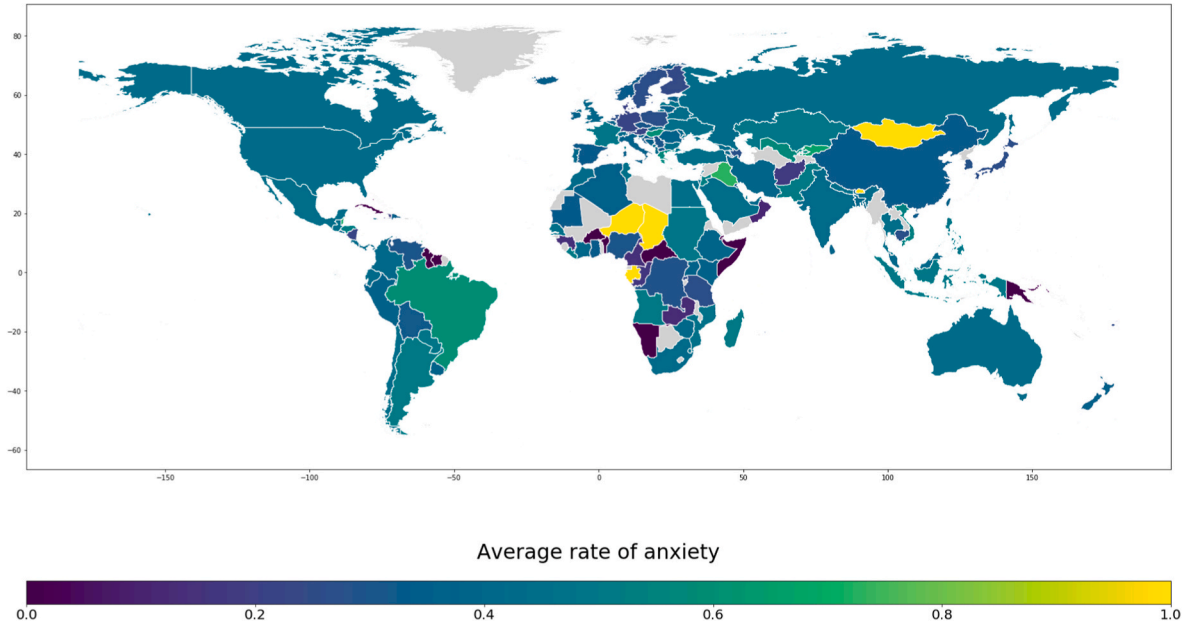

Fig. 1. Geographical heterogeneity in average rates of anxiety.

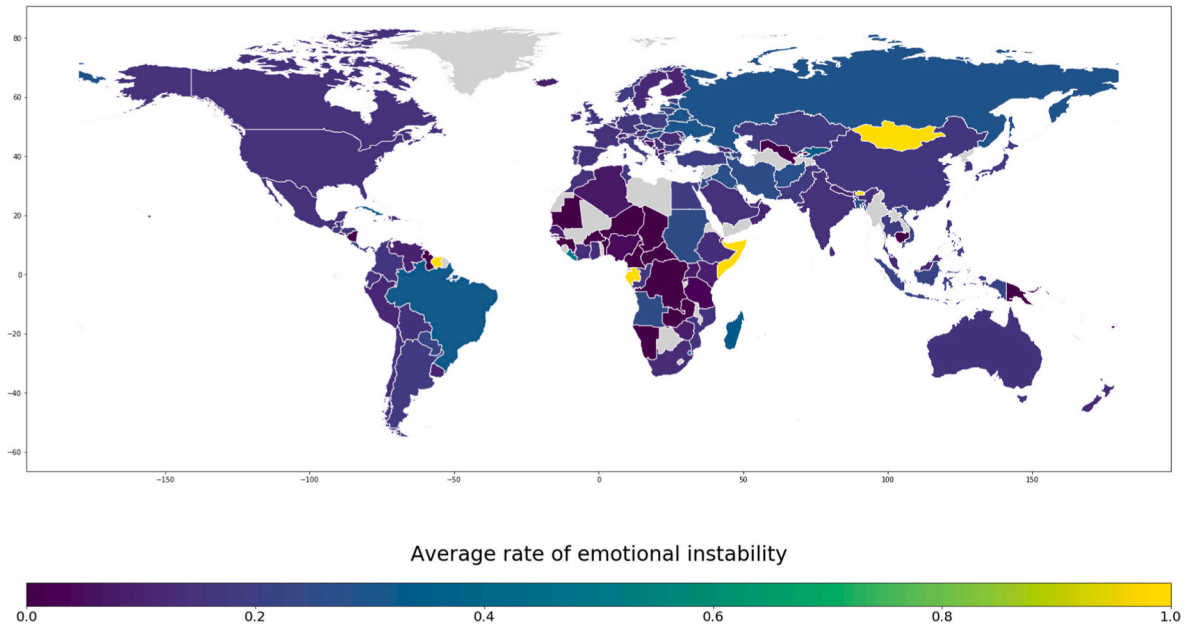

Fig. 2. Geographical heterogeneity in average rates of emotional instability.

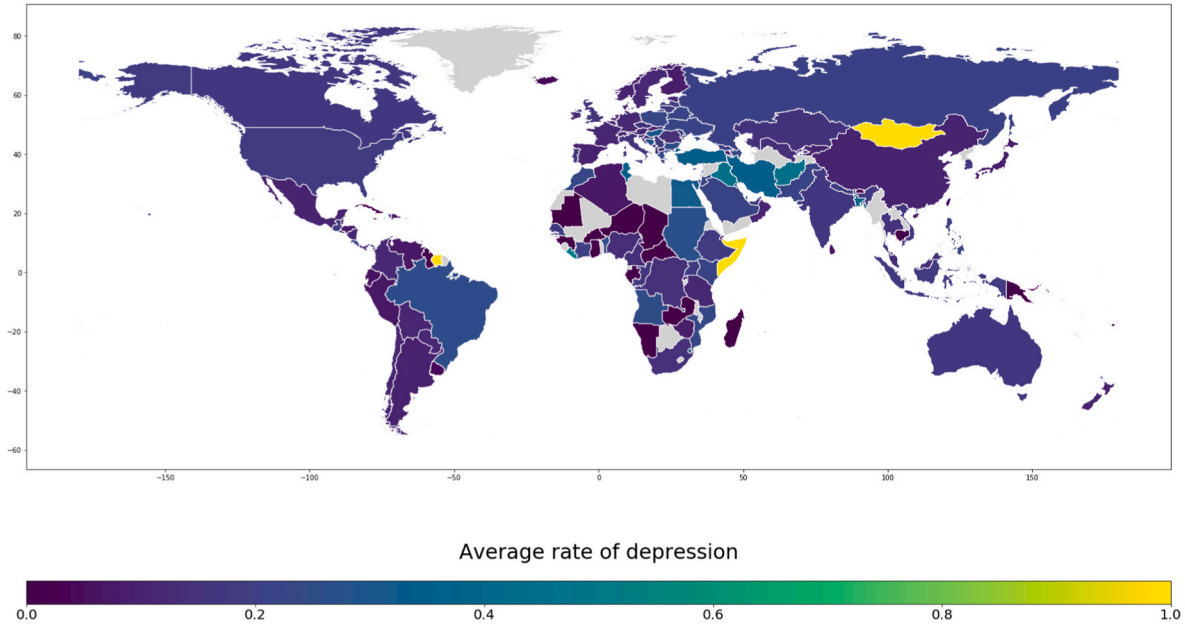

Fig. 3. Geographical heterogeneity in average rates of depression.

variation in seasonality that are common across countries in a continent during the month of a given year. The estimating equation clusters standard errors at the country level to allow for an arbitrary auto-correlation process within the country.

Three methodological issues are worth pointing out. First, correlations between individual mental health outcomes and reported virus cases at the country level are subject to ecological fallacy. This situation arises when researchers aim to infer relationships between micro-level units (like individuals) from larger, more aggregated units (like countries) that contain micro-level units. According to Banzhaf et al. (2019), the relationship estimated from aggregated data is only equal to the relationship at the micro-level if there are no group-level effects correlated with outcome variables. Given that this extreme assumption is not likely to hold, the estimation procedure of this study will be susceptible to ecological fallacy.

Second, it is possible that a limited number of testing facilities in different countries may have caused a fewer number of reported cases of the virus (Paudel, 2021d). It is also likely that actual rates of COVID-19 infection may exceed the number of confirmed cases reported (Li et al., 2020). To some extent, a suite of fixed effects that vary across both spatial locations and time periods accounts for potential heterogeneous under-reporting across space and time. Yet, it is well-known that some countries such as the UK and India did not have adequate community testing facilities at the onset of the pandemic except for frontline workers. This potential limitation, which applies to every COVID-19 related research that looks at the estimated intensity of the COVID-19 pandemic, needs to be taken into account when interpreting the findings of this study.

Finally, the cross-sectional nature of data employed in this study implies that estimates need to be interpreted cautiously. Although there

are no missing data observations that rule out the need for imputation strategies (Sidi and Harel, 2018), the sampling procedure applied to collect individual-level data on mental health outcomes is prone to selection bias. The survey may have attracted participants who are more concerned about the COVID-19 pandemic than other citizens in their countries, which creates potential concerns for self-selection bias. These methodological issues need to be considered when interpreting the estimates of this study.

4. Results

4.1. COVID-19 and mental health

Table 3 presents the main regression results that evaluate the association between the coronavirus outbreak intensity and three indicators of mental well-being: anxiety, emotional instability and depression. Column (1) shows that an additional unit reported case of COVID-19 per 1000 residents is associated with an 11.83 % (95 % CI [-2.05 %, 25.71 %]) increase in the probability of an individual respondent feeling anxious and easily upset. The association between virus outbreak intensity and an individual's anxiety, which is statistically significant at the 10 % level with a p-value of 0.094, is consistent with an influx of studies with different sample sizes across different settings (Zhang and Ma, 2020; Ahmed et al., 2020; Cao et al., 2020; Wang et al., 2020; Ueda et al., 2020; Fetzer et al., 2020). Fig. 4 breaks down the association between COVID-19 virus outbreak intensity and anxiety across different sizes of a household. The change in anxiety in the aftermath of the pandemic is negligible among respondents with 0–2 people in the household. However, the association between virus outbreak intensity and anxiety appears to be more pronounced among respondents with 3–6 people in the household and it starts to decline further with an increase in household size. Column (2) finds that there does not exist a strong association between the COVID-19 virus outbreak intensity and a measure of individuals' emotional instability. Column (3) shows that for every additional unit reported case of COVID-19 per 1000 residents, individuals are 10.50 % (95 % CI [-5.74 %, 26.74 %]) likely to find life depressing. However, this association is not statistically significant with a p-value of 0.204.

Table 3 displays the contemporaneous effect of the pandemic on mental health outcomes. A change in the virus outbreak intensity is likely to have behavioral implications beyond the time period in which such cases are reported. The effect of current-day virus cases on an individual's mental well-being can extend to future days. To delve into this issue further, the study augments equation (1) with lagged values of COVID-19 cases per 1000 residents up to four days. This approach, which assumes that individual outcomes in future period depend on past values, is commonly used to investigate the dynamic effect of a treatment on outcomes in applied econometric studies focused on environment and transportation (Paudel, 2021c,b,a). Table A2 shows that the intensity of previously reported virus-related cases is significantly associated with the likelihood of an individual feeling anxiety and emotional instability. Column (2) shows that anxiety is positively associated with one-day lagged and four-day lagged reported virus cases per 1000 residents. Column (2) indicates that the likelihood of an individual feeling emotional instability is positively associated with two-day lagged reported virus cases per 1000 residents. Future research may benefit from employing longitudinal data on individuals to explore both short-term and long-term effect of the pandemic on mental health outcomes.

Table 3
Association between COVID-19 virus outbreak intensity and mental health outcomes.

	Anxious	Unstable	Depressing
	(1)	(2)	(3)
Virus cases (per 1000)	0.1183*	−0.1159	0.1050
	(0.0702)	(0.0815)	(0.0822)
	[-0.0205,0.2571]	[-0.2769,0.0451]	[-0.0574,0.2674]
N	111643	111643	111643
R-Squared	0.2064	0.1961	0.1905
Day Fixed Effects	Yes	Yes	Yes
Continent-by-Month Fixed Effects	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Notes: Standard errors, in parentheses, are clustered at the country level. 95 % confidence intervals are reported in square brackets. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level and * indicates significance at the 10 % level.

4.2. COVID-19 and mental health across continents

Table 4 explores the heterogeneity in the association between COVID-19 virus outbreak intensity and mental health outcomes across five continents: Africa, Americas, Asia, Europe and Oceania. To generate insights on which regions are more susceptible to adverse mental health outcomes associated with the virus outbreak, the study estimates equation (1) across five different sub-samples. The only difference in this empirical exercise is that the estimating equation does not control for month-by-continent fixed effects. Panel A in Table 4 shows that the short-run association between the virus outbreak intensity and anxiety is positive and statistically significant in Africa, negative and statistically significant in Oceania, ambiguous and statistically insignificant in Americas, Asia and Europe. Panel B demonstrates that there is statistically significant association between the virus outbreak intensity and a measure of individual's emotional instability across three continents: Africa, Americas, and Oceania. Although the magnitudes of these slope coefficients appear to be large, it is worth pointing out that less than 4 % of the entire sample comprises of Africa and Oceania. The slope coefficient in the case of Europe is consistent with main results obtained in Table 3. Finally, Panel C shows that the association between virus outbreak intensity and depression is positive and statistically significant in Europe and negative and statistically significant in Africa. Notably, the short-run increase in the likelihood of finding life depressing for every additional reported case of the virus (per 1000 individuals) is strong in Europe (16.15 %, 95 % CI [2.22 %, 30.09 %]), contrary to the effect documented in Africa.

Taken together, this empirical exercise provides insights on which countries are more susceptible to adverse mental health outcomes associated with COVID-19 virus outbreak intensity. Estimates generated in the study can be used to determine which countries to target, and identify timely and cost-effective policies for improved mental health services. However, these differences in the association between virus outbreak intensity and mental health outcomes across different continents need to be interpreted with caution. The first caveat is that it is difficult to precisely estimate slope coefficients for Africa and Oceania, as there are relatively fewer observations across these regions. The second caveat, which is highlighted in Belot et al. (2020), is that there may exist unobservable region-specific differences attributed to different cultures, trust, and institutional strength. It is worth mentioning that these differences are indirectly captured through country-level fixed effects to some extent. However, future researchers may delve into unobservable heterogenous responses to the pandemic for a more rigorous examination of this topic.

4.3. COVID-19 and mental health across gender

Table 5 breaks down the main regression results evaluating the association between the coronavirus outbreak intensity and indicators of mental well-being across male and female respondents in the sample. Three results are worth highlighting: First, the association between virus

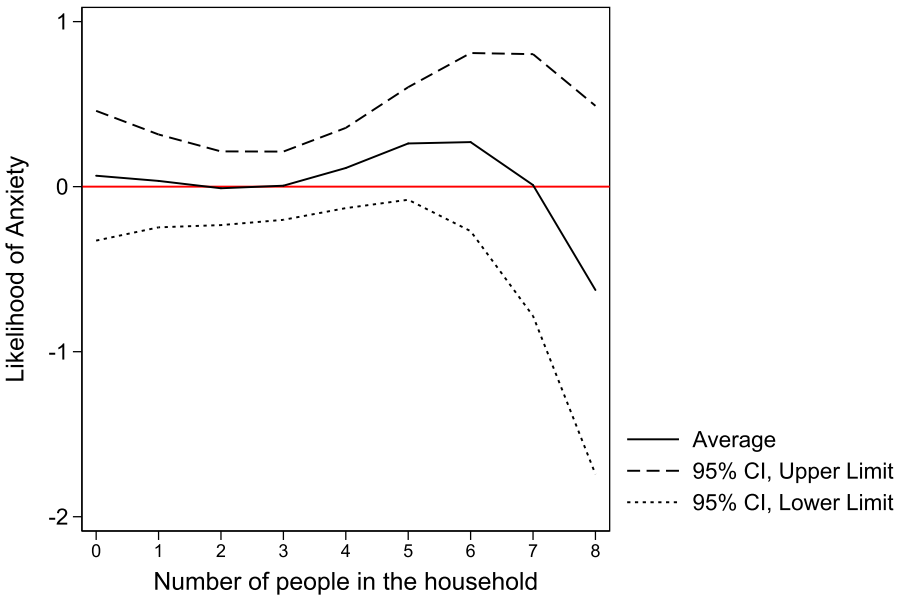

Fig. 4. Association between COVID-19 virus outbreak intensity and anxiety across different sizes of the household.

Table 4
Association between COVID-19 virus outbreak intensity and mental health outcomes across continents.

	Africa	Americas	Asia	Europe	Oceania
	(1)	(2)	(3)	(4)	(5)
Panel A, Dependent Variable: Anxious					
Virus cases (per 1000)	39.2796*	−0.0334	0.0668	0.0611	−16.6703**
	(22.3203)	(0.1407)	(0.6251)	(0.0694)	(1.7049)
	[-6.0330,84.5923]	[-0.3207,0.2539]	[-1.1986,1.3323]	[-0.0792,0.2014]	[-24.0060,-9.3345]
N	2225	36922	12426	58752	1318
R-Squared	0.4898	0.2706	0.3598	0.1599	0.2010
Day Fixed Effects	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Panel B, Dependent Variable: Unstable					
Virus cases (per 1000)	−26.4607***	−0.2223*	−0.0299	−0.0385	−8.1986**
	(6.0598)	(0.1283)	(0.3664)	(0.0550)	(1.4166)
	[-38.7627,-14.1587]	[-0.4844,0.0397]	[-0.7715,0.7118]	[-0.1495,0.0725]	[-14.2939,-2.1032]
N	2225	36922	12426	58752	1318
R-Squared	0.5014	0.2921	0.5174	0.0727	0.2221
Day Fixed Effects	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Panel C, Dependent Variable: Depressing					
Virus cases (per 1000)	−35.8210*	−0.2814*	0.6818	0.1615**	3.1310**
	(18.7186)	(0.1530)	(0.4107)	(0.0690)	(0.6729)
	[-73.8218,2.1798]	[-0.5939,0.0311]	[-0.1496,1.5131]	[0.0222,0.3009]	[0.2360,6.0261]
N	2225	36922	12426	58752	1318
R-Squared	0.6980	0.2548	0.3028	0.1604	0.2054
Day Fixed Effects	Yes	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors, in parentheses, are clustered at the country level. 95 % confidence intervals are reported in square brackets. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level and * indicates significance at the 10 % level.

outbreak intensity and anxiety is strong and positive among both males and females. Column (1) and Column (2) indicates that males and females are 17.45 % (95 % CI [-0.56 %, 35.47 %]) and 19.19 % (95 % CI [-1.09 %, 39.47 %]) likely to feel anxious for every additional reported case of COVID-19 per 1 thousand people. Second, there does not exist a statistically significant association between virus outbreak intensity and emotional instability among both males and females, which is consistent with the primary results in Table 3. Finally, the study finds compelling evidence that virus outbreak intensity can exacerbate gender disparities in mental well-being. Column (5) indicates that an additional reported case of COVID-19 per 1000 residents does not have a significant relationship with the likelihood of depression among males, but is associated with a 20 % (95 % CI [6.65 %, 33.39 %]) increase in the probability of a female respondent feeling depressed.

Table 5
Association between COVID-19 virus outbreak intensity and mental health outcomes.

	Anxious		Unstable		Depressing	
	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)
Virus cases (per 1000)	0.1745*	0.1919*	−0.0644	−0.0767	−0.1181	0.2002***
	(0.0912)	(0.1026)	(0.0843)	(0.0994)	(0.1087)	(0.0676)
	[-0.0056,0.3547]	[-0.0109,0.3947]	[-0.2310,0.1022]	[-0.2732,0.1199]	[-0.3329,0.0967]	[0.0665,0.3339]
N	48687	62956	48687	62956	48687	62956
R-Squared	0.2975	0.2843	0.2826	0.2469	0.2431	0.2531

Notes: Each specification includes day fixed effects, continent-by-month fixed effects, country fixed effects and control variables. Standard errors, in parentheses, are clustered at the country level. 95 % confidence intervals are reported in square brackets. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level and * indicates significance at the 10 % level.

5. Discussion

5.1. The role of staying at home

This section investigates whether negative association between virus outbreak intensity and mental health is statistically different between (i) individuals who stayed at home for the past week and their counterparts who did not stay at home for the past week, and (ii) individuals who avoided social gatherings for the past week and their counterparts who did not avoid social gatherings. This analysis is worth exploring because increased loneliness and reduced in-person interactions during the pandemic are potential risk factors for depression and obsessive-compulsive disorders (Fiorillo and Gorwood, 2020).

Results from Table 6 indicate that staying at home may be a potential channel that explains the linkage between virus outbreak intensity, anxiety and emotional instability. For example, the double interaction term between virus outbreak intensity and staying at home in Column (1) shows that the association between COVID-19 pandemic and anxiety is 14.81 % (95 % CI [3.46 %, 26.16 %]) more among individuals who stayed at home during the last week (compared to their counterparts who did not). Similarly, the double interaction term between virus outbreak intensity and staying at home in Column (2) shows that the association between COVID-19 pandemic and emotional instability is 11.17 % (95 % CI [2.13 %, 20.21 %]) more among individuals who stayed at home during the last week (compared to their counterparts who did not). Fig. 5 plots the average coefficients and 95 % confidence intervals associated with the double interaction term between virus outbreak intensity and staying at home in Table 6. The double interaction term between virus outbreak intensity and staying at home is statistically significant at the 5 % level in the case of anxiety and emotional instability.

Table 6
Mechanism behind mental health outcomes the association between COVID-19 virus outbreak intensity and.

	Anxious (1)	Unstable (2)	Depressing (3)
Virus cases (per 1000)	0.0654	−0.1201	0.1273
	(0.0952)	(0.0787)	(0.1043)
	[-0.1227,0.2535]	[-0.2757,0.0354]	[-0.0788,0.3333]
Stayed home	−0.0848**	−0.0908**	0.0207
	(0.0420)	(0.0421)	(0.0236)
	[-0.1678,-0.0018]	[-0.1739,-0.0076]	[-0.0260,0.0674]
Stayed home*Virus cases	0.1481**	0.1117**	0.0151
	(0.0574)	(0.0458)	(0.0383)
	[0.0346,0.2616]	[0.0213,0.2021]	[-0.0605,0.0907]
No social gatherings	0.0121	0.0317	0.0158
	(0.0434)	(0.0289)	(0.0336)
	[-0.0737,0.0979]	[-0.0255,0.0888]	[-0.0505,0.0822]
No social gatherings*Virus cases	−0.0065	−0.0442	−0.0382
	(0.0659)	(0.0420)	(0.0546)
	[-0.1368,0.1238]	[-0.1273,0.0389]	[-0.1461,0.0697]
N	111,643	111,643	111,643
R-Squared	0.2110	0.2090	0.1921

Notes: Each specification includes day fixed effects, continent-by-month fixed effects, country fixed effects and control variables. Standard errors, in parentheses, are clustered at the country level. 95 % confidence intervals are reported in square brackets. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level and * indicates significance at the 10 % level.

5.2. Implications of household size

The analysis in the preceding section showed that the association between the pandemic and anxiety is possibly larger in magnitude among individuals who stayed at home during the last week compared to those who did not stay at home. To explore this further, this section investigates whether household size exacerbates the linkage between virus outbreak intensity and anxiety among individuals who stayed at home and their respective counterparts.

Fig. 6 provides evidence that the differential relationship between COVID-19 virus outbreak intensity and anxiety between individuals staying at home and their counterparts not staying at home may increase with household size, with 11 % (95 % CI [-4.65 %, 28.11 %]) among individuals with 0–1 members in the household, 12 % (95 % CI [1.89 %, 23.20 %]) among individuals with 2–3 members in the household and 20 % (95 % CI [5.73 %, 36.31 %]) among those with 4–8 members in the household (see Fig. 6). Although the same increasing pattern emerges in the case of emotional instability, coefficient estimates of the double interaction term across different household sizes in Fig. 7 are not statistically significant.

5.3. Limitations

It is worth highlighting that the empirical analysis conducted above has some limitations. First, it is important to note that none of the double interaction terms between virus outbreak intensity and no social gatherings in Table 6 are statistically significant. While it is beyond the scope of this study to causally identify the channel behind the documented association between the pandemic and mental health outcomes, estimates from Table 6 provide suggestive evidence that staying at home may result in anxiety and emotional instability induced by the pandemic. Second, the explanation of household size as a channel that may worsen the linkage between virus outbreak intensity and emotional instability does not hold true in Fig. 7. This is primarily because coefficient estimates of the double interaction term across different household sizes are not statistically significant concerning emotional instability. This implies that future research may benefit from exploring the repercussions of COVID-19 virus outbreak intensity on a wide range of health outcomes across individuals belonging to different household sizes. Finally, the main regression findings on the statistical association between the coronavirus outbreak intensity and anxiety are based on p-values close to 0.10. For example, Table 3 shows that an 11.83 % (95 % CI [-2.05 %, 25.71 %]) increase in the probability of an individual respondent feeling anxious in response to an additional unit reported

Fig. 5. Association between COVID-19 virus outbreak intensity and mental health outcomes between individuals staying at home over the past week and those not staying at home.

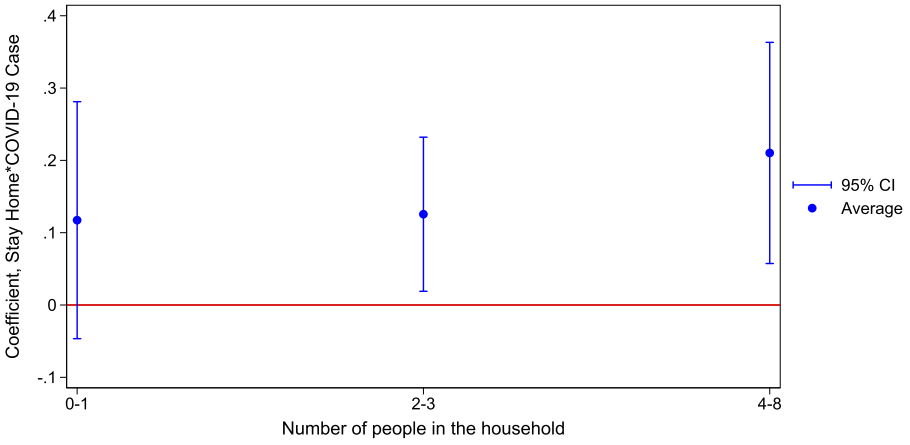

Fig. 6. Heterogenous association between COVID-19 virus outbreak intensity and anxiety among individuals staying at home during the last week across different sizes of the household.

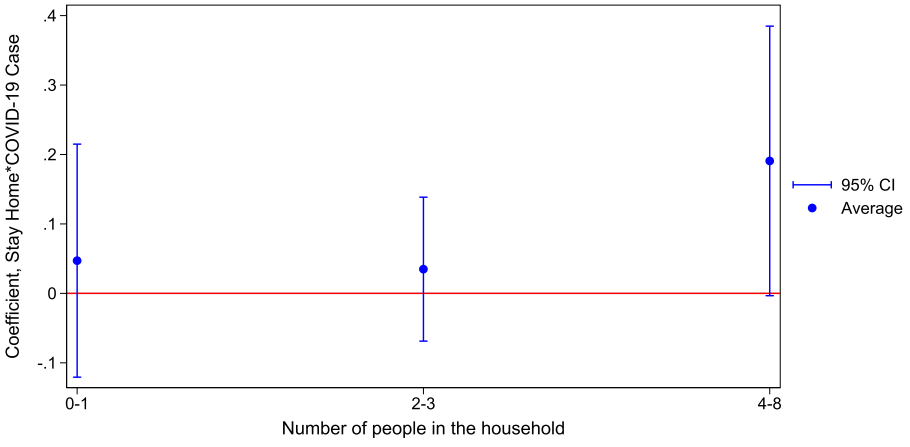

Fig. 7. Heterogenous association between COVID-19 virus outbreak intensity and emotional instability among individuals staying at home during the last week across different sizes of the household.

case of COVID-19 per 1000 residents is statistically significant only at the 10 % level. Similarly, estimates of 17.45 % (95 % CI [-0.56 %, 35.47 %]) and 19.19 % (95 % CI [-1.09 %, 39.47 %]) on the association between anxiety and virus outbreak intensity among males and females documented in Table 5 are also based on p-values close to 0.10. These limitations need to be considered when interpreting the estimates of this study.

5.4. Economic and policy implications

As recent projections show that the direct cost of treating mental disorders is growing at 5 % annually (Roehrig, 2016), short-run mental

health damages associated with COVID-19 documented in the study have direct implications for long-term mental health outcomes, which are also associated with increased risk of physical illnesses (Kolappa et al., 2013). To provide a concrete illustration of the magnitude of the estimated impact, the study combines the results from Table 3 with findings from prior studies and estimates the overall societal cost imposed by mental health changes resulting from virus outbreak intensity. For example, Kessler et al. (2008) determine that total annual loss in earnings associated with poor mental health among individuals aged between 18 and 64 is approximately $ 193.2 billion. It is worth pointing out that this estimate does not consider other societal costs (such as lost productivity or welfare) associated with mental poor mental health, implying that $193.2 billion is an estimate of a single component of the overall societal cost of poor mental health in a given year. Combining this estimate with the slope parameter of 0.1183 from Table 3 allows us to generate the change in loss of earnings from mental anxiety associated with COVID-19 virus outbreak intensity. This step results in an annual loss of earnings of $22.8 billion. Relatedly, Trautmann et al. (2016) apply the value of a statistical life (VSL) approach to conclude that the global economic burden of poor mental health is $8.5 trillion. To generate a back-of-the-envelope calculation on global economic cost of poor mental health induced by the pandemic, findings from Trautmann et al. (2016) can be combined with estimated parameters in this study. This corresponds to an amount of $1.00555 trillion, which is equivalent to 4.76 % of the US real Gross Domestic Product (GDP).

6. Conclusions

The current study examined the short-term association between COVID-19 virus outbreak intensity and an individual's anxiety, emotional instability and depression across the globe. To assess the changes in mental health outcomes in the aftermath of the virus outbreak, the study combined publicly available individual-level data from a large-scale survey with daily number of reported virus cases covering 151 countries for the period between March 20, 2020 and April 16, 2020. Controlling for country fixed effects, day fixed effects, month-by-continent fixed effects and demographic characteristics, estimates indicate that an additional reported case of COVID-19 per 1000 residents is associated with an 11.83 % (95 % CI [-2.05 %, 25.71 %]) increase in the likelihood of an individual respondent feeling anxious and easily upset. This finding is based on a p-value close to 0.094. The association between the pandemic and mental health is more pronounced among individuals staying at home for the past week, who are 14.81 % (95 % CI [3.46 %, 26.16 %]) more likely to feel anxious and 11.17 % (95 % CI [2.13 %, 20.21 %]) more likely to experience emotional instability than their counterparts. Results further show that the association between virus outbreak intensity and the likelihood of anxiety among individuals staying at home increases with household size, ranging from 11.73 % (95 % CI [-4.65 %, 28.11 %]) among individuals with 0–1 members in the household to 21.02 % (95 % CI [5.73 %, 36.31 %]) among those with 4–8 members in the household.

Results from this study indicate that females may bear a much larger mental health burden than males during the COVID-19 pandemic. This suggests that policymakers need to work towards creating equitable policy interventions aimed at minimizing gender disparities in mental health consequences of the pandemic. Short-run estimates of association between virus outbreak intensity and mental health outcomes across different population sub-groups contribute to our understanding of the overall social cost of pandemics across the globe. These estimates also provide insights on which regions are more susceptible to adverse mental health outcomes associated with COVID-19 virus outbreak intensity. This information can be used to determine which countries to target, and identify timely and cost-effective policies for improved mental health services.

Sample credit author statement

Jayash Paudel: Conceptualization, Methodology, Writing – original draft preparation, Visualization, Investigation, Writing- Reviewing and Editing,

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2021.114259.

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