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COVID-19 大流行對精神健康的影響：

使用 42 國 Google 搜尋資料進行時間序列分析

The Impact of the COVID-19 Pandemic on Mental
Health in 42 Countries: Time Series Analysis Using
Google Trends Data

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研究背景：

在 COVID-19 大流行期間，疫情對心理健康造成的負面影響受到重視，然而疫情期間許多研究採用便利性樣本，受選擇性偏差影響，有代表性的問題，研究對象僅限於特定地區或國家，因此本篇研究透過網路搜尋引擎資料進行分析比較，了解本次疫情對不同國家之人群造成的心理健康影響。

研究方法：

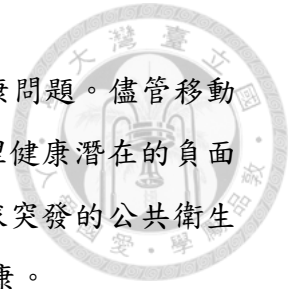
本研究收集來自 Google Trends 資料庫 42 國「焦慮」、「失眠」、「孤獨」、「憂鬱」及「自殺」五個字詞的搜尋變化，採用季節性差分整合移動平均自迴歸模型 (seasonal-ARIMA model)，以 2016 至 2020 年共 217 週之資料預測 2020 年 3 月至 2021 年 2 月共 53 週之搜尋量，了解疫情期間各字詞之搜尋量與預期值相比之變化；並使用斯皮爾曼等級相關 (Spearman Rank Correlation) 分析字詞搜尋量增加之週數與各國 GDP 成長率、失業率以及基尼係數之關係；並以隨機效應模型 (Random effects model) 分析各字詞 53 週實際值與預測值之差值與 COVID-19 確診率、死亡率及疫情間人流移動變化之關係。

結果：

本篇研究所納入的五個字詞「焦慮」、「孤獨」、「失眠」、「憂鬱」、「自殺」在 42 個國家中呈現隨著時間在疫情爆發後的 53 週呈現不同的變化。「焦慮」一詞之搜尋量增加的平均週數最高(6.86 週)，其次為「失眠」(5.05 週)，「自殺」(1.57 週)，「孤獨」(1.00 週)，與「憂鬱」(0.67 週)。相較下，「憂鬱」搜尋量下降的平均週數為 3.1 週。相關分析顯示 GDP 成長與基尼係數與「焦慮」和「失眠」之搜尋量增加週數有關。迴歸分析顯示，行動限制與「焦慮」、「孤獨」、「失眠」之搜尋量增加有關，而疫情爆發的嚴重度(以 COVID-19 確診率或死亡率為指標)與「焦慮」、「失眠」和「憂鬱」的搜尋量增加有關。

結論：

焦慮和失眠症狀可能是 COVID-19 疫情第一年常見的心理健康問題。儘管移動限制政策有助於控制疫情，但各國政府仍應警惕其對大眾心理健康潛在的負面影響，而充分的疫情控制有助於保護人們的心理健康。在全球突發的公共衛生事件期間，Google Trends 資料有助於即時監測大眾的心理健康。

**關鍵字：**

COVID-19、Google Trends、心理健康、焦慮、失眠、孤獨、憂鬱、自殺

Abstract



Introduction:

There were concerns that the COVID-19 pandemic would adversely impact population mental health. However, most surveys used non-probability and convenience samples, which were susceptible to selection bias, and were restricted to specific communities or countries. This study aimed to investigate the impact of the COVID-19 outbreak on population mental health across different countries using population-based internet search data using mental health-related keywords.

Methods:

We extracted Google Trends data from 42 countries using five search terms: “anxiety”, “insomnia”, “loneliness”, “depression” and “suicide”. We used seasonal Autoregressive Integrated Moving Average (ARIMA) model to estimate the expected Google search volume during the COVID-19 pandemic (March 2020 – February 2021) based on pre-pandemic trends (January 2016 – February 2020). We first conducted Spearman correlation analysis to investigate the association between the total number of weeks with a change in Google search volume (i.e., whether the observed search volume was above or below the 95% confidence intervals of the expected volume) and GDP growth rate, unemployment rate, and Gini index across countries. We then applied random-effects models to investigate the associations of the weekly Google search volume difference (i.e., the observed value minus the expected value) with the weekly number of COVID-19 confirmed cases, the weekly number of COVID-19 death, and the weekly residential mobility change across the 42 study countries.

Results:

Changes in the Google search volume of five mental health related terms showed

varying trends across the 42 study countries during the first 53 weeks of the COVID-19 outbreak. Search for “anxiety” had the highest mean number of weeks with increased search volume (6.86), followed by “insomnia” (5.05), “suicide” (1.57), “loneliness” (1.00), and “depression” (0.67). By contrast, search for “depression” also had a mean number of weeks with decreased search volume of 3.10. Correlation analyses showed that GDP growth and Gini index were associated with searches for “anxiety” and “insomnia”. Regression analyses showed that restriction on movement was associated with increased searches for “anxiety”, “loneliness”, and “insomnia” but decreased searches for “depression”. The severity of the COVID-19 outbreaks, indicated by rates of confirmed cases or mortality, was associated with increased searches for “anxiety”, “insomnia”, and “depression”.

Conclusions:

Anxiety and insomnia symptoms might be the common mental health problems during the first year of the COVID-19 pandemic. Although movement restriction policies would help control the outbreak, governments should be alert to the potential negative mental health effects on the population. Adequate virus outbreak control would also protect the population’s mental health. During the worldwide public health emergency, Google Trends data could be useful to monitor population mental health in real time.

Keywords:

COVID-19, Google Trends, mental health, anxiety, insomnia, loneliness, depression, suicide

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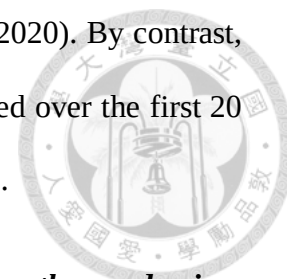
Chapter 1 Introduction

The COVID-19 outbreak had posed severe challenges to countries around the world since the beginning of 2020. The World Health Organization (WHO) declared the COVID-19 outbreak a pandemic in March 2020. The outbreak impacted various areas, such as agriculture, manufacturing industry, education, finance industry, healthcare industry, hospitality, tourism and, aviation (Nicola et al., 2020). At the individual level, apart from the threat to physical health, more and more studies indicated negative impacts on the mental health of the pandemic. In March 2020, the WHO published a report listing different possible mental health and psychosocial effects of the pandemic and called for governments' attention and efforts to support mental and psychosocial well-being in different vulnerable groups during the outbreak (World Health Organization, 2020). Mental health researchers also called for action for more high-quality studies of the mental health impact of the pandemic (Holmes et al., 2020).

1.1 Mental health impact of the COVID-19 Pandemic on the general population

Although some studies focused on the mental health impact of the pandemic in certain high-risk groups, such as infected people, their families and colleagues, individuals with pre-existing physical or mental conditions, and healthcare providers (Torales, O'Higgins, Castaldelli-Maia, & Ventriglio, 2020), others indicated possible adverse effects in the general population. For example, a study conducted in the UK showed increases in anxiety and lower well-being in the population during the COVID-19 pandemic (Kwong et al., 2020). Another longitudinal study revealed that in the UK, the prevalence of mental distress in the population rose from 18.9% in 2018–19 to 27.3% in April, 2020, one month after the lockdown (Pierce, Hope, et al., 2020). In the US, the prevalence of depression symptoms was more than three times higher during the

pandemic compared with that before the pandemic (Ettman et al., 2020). By contrast, another study found that anxiety and depression levels both declined over the first 20 weeks of the lockdown in England (Fancourt, Steptoe, & Bu, 2021).



1.2 Factors associated with negative mental health outcomes during the pandemic

There are several potential factors that may lead to negative impacts on mental health during the pandemic. First, during this pandemic, many countries announced their own restriction policies, such as lockdowns, school closings, workplace closing, canceling public events, restrictions on gathering size, closed public transport and stay-at-home requirements, these all hugely influenced people's original life (Thomas Hale, 2020). For example, increased phone usage, decreased physical activity, and fewer locations visited. These behavior changes were found to be associated with COVID-19 news reporting and had negative impact on college students (Huckins et al., 2020). A study conducted in Italy also found that people increased the usage of digital media near bedtime, and sleep behavior markedly changed (Cellini et al., 2020).

Second, restriction policies like social distancing not only pulled people away physically but also increased the psychological burden. A rapid review summarized that stressors cause by quarantine during the previous pandemic included infection fears, frustration, boredom, inadequate supplies, inadequate information, financial loss, and stigma (Brooks et al., 2020). Another key factor, loneliness, was the main risk factor for depression, anxiety, and especially elderly's comorbidity (Palgi et al., 2020). Besides loneliness, intolerance to uncertainty and COVID-19-related worry were also found to be insomnia-predictive factors (Voitsidis et al., 2020). Compare to previous Pandemic such as SARS, MERS, and Ebola, the COVID-19 pandemic lead to even longer quarantine time, more attention should be paid to the negative psychological

effects.

Apart from the reasons above, problematic social media use (Lin, Brostrom, Griffiths, & Pakpour, 2020), repeated media exposure to community crises (Garfin, Silver, & Holman, 2020), social discrimination (Wang et al., 2020), lower social resources, lower economic resources, and greater exposure to stressors (eg, job loss) are all factors that associated with poor mental health outcome (Ettman et al., 2020).

Suicide researchers have used data from various sources to investigate the potential effect of the COVID-19 pandemic on population mental health. Studies include cross-sectional survey studies with data on changes in the prevalence and correlates of mental problems such as anxiety and depression, and service utilization data on trends in hospital admissions for psychiatric symptoms or disorders. However, most of these study designs are insufficient to investigate continuous changes in mental health. Furthermore, health-care utilization data could be affected by pandemic-related restrictions on access to health services (John et al., 2021).

Eysenbach defined “infodemiology” as “the science of distribution and determinants of information in an electronic medium, specifically the Internet, or in a population, with the ultimate aim to inform public health and public policy.” There are several online sources that can be used, such as Google, Facebook , Twitter, and electronic health records (Eysenbach, 2009). Among these, the most popular infodemiology data is Google Search engine data, which can be retrieved from Google Trends (<https://trends.google.com.tw/>). Google Search engine data has several strengths. First, it allows researchers to obtain information that used to be difficult or impossible to collect. Second, it provides data in real-time, which saves much time and effort

compared to traditional survey methods. Finally, it can be obtained anonymously, thus enabling researchers reach to sensitive topics without revealing user's personal information (Mavragani & Ochoa, 2019).



A recent study from Taiwanese researchers analyzed google search data using two keywords, “insomnia” and “suicide”, across 45 countries during the first year of the COVID-19 pandemic (March 1, 2020 to February 28, 2021) (Lin et al., 2023). The results showed that countries’ numbers of COVID-19 deaths were positively associated with searches for “insomnia” and negatively associated with searches for “suicide”. There was evidence that stay-at-home levels (indicated by the time of cell phone activity at the residence from Google Location History) mediated the association between COVID-19 deaths and google searches for “insomnia” in the first six months, but not the next six months, during the first year of the pandemic. By contrast, the mediation effect was found for the association between COVID-19 deaths and google searches for “suicide” in the second six months, but not in the first six months, of the first year of the pandemic. The results indicated that the outbreak mitigation measures, indicated by the stay-at-home level, mediated the impact of the COVID-19 pandemic on mental health. However, this study only investigated google searches for “insomnia” and “suicide”, but not other potential mental health related keywords, such as anxiety, loneliness, and depression, which have been used in previous other studies of the COVID-19 pandemic impact on mental health (Sinyor et al., 2020).

1.3 Aim of the study

We aimed to investigate cross-country and temporal variations in mental health during the first year of the COVID-19 pandemic, relative to that expected based on pre-pandemic trends, using Google Trends data, i.e., trends in internet search using mental health-related keywords. We also examined the associations of such variations with outbreak severity indicators and the impacts of the government's outbreak control measures on population mobility and countries' economies.

Chapter 2 Method

2.1 Google search data

Data for Google search volume were retrieved from Google Trends (<https://trends.google.com.tw/>). Google Trends normalizes search interest data into relative search volume (RSV), which represents the search interest using specific keywords on Google as a proportion of the highest search volume using these keywords over a given time period and location. RSVs could range from 0 to 100, where 100 is the maximum search volume for the time period and location selected. We used five search terms “anxiety”, “loneliness”, “insomnia”, “depression”, and “suicide” to represent the status of mental health distress. Considering that “depression” has a different meaning when it comes to the economy, we only used “depression” that related to the topic of “health” in order to capture the search volume related to mental health that we would like to focus on. We have also considered other search terms such as “panic”, “lonely”, and “stress”. However, based on data from Google Trends, we found that these search terms may not be specific to mental health. For instance, a substantial proportion of searches related to ‘panic’ were in fact associated with “panic buying”, instead of the meaning related to mental health that we would like to capture, and thus these search terms were excluded. We used back-translation on Google

Translate (<https://translate.google.com/>) to ensure the correct translation of these five keywords into different languages (see Supplement Table 1). For countries that have two official languages, we chose the language that has a relatively higher search volume. For example, we used English rather than Chinese search terms for Singapore.

We extracted Google search data for 270 weeks from the first week of 2016 (2016/01/03-2016/01/09) to the last week of February 2021 (2021/2/22-2021/02/28) in 42 countries. We included countries that have over 50% internet penetration (https://en.wikipedia.org/wiki/List_of_countries_by_number_of_Internet_users) and countries where Google is the major internet search engine used. Internet percentage was the percentage of a country's population that are internet users, who are defined as persons who accessed the internet in the last 12 months from any device. Most African countries were excluded because their internet penetration rates were low. China was also excluded since Baidu was the main search engine used there instead of Google. We also excluded countries with three or more national languages such as Switzerland, India, and South Africa as well as countries with two official languages that were equally dominant on Google such as Belgium. The 42 countries we selected in this study included 13 countries in Asia, 2 countries in Oceania, 17 countries in Europe, 7 countries in South America, 2 countries in North America, and 1 country in Africa (Figure 1).

2.2 Data for COVID-19 related and socioeconomic variables

Data for the following variables were collected in each study country - (1) COVID-19 confirmed cases; (2) COVID-19 deaths; (3) residential mobility change during the pandemic; (4) GDP growth rate; (5) unemployment rate and (6) Gini index. Data for

COVID-19 confirmed cases and deaths were from COVID-19 Data Repository maintained by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (<https://systems.jhu.edu/>). Data for GDP growth rate and unemployment rate were from International Monetary Fund (<https://www.imf.org>), and Gini index data were from The World Bank (<https://www.worldbank.org>).

The residential mobility change data were from Google Community Mobility Reports (<https://www.google.com/covid19/mobility/>). Google Community Mobility Reports show population movement trends by region, across different categories of places. The reports are based on aggregated, anonymized sets of data from Google users who have turned on the “location history” setting. The data show how the volume of visitors traveling to (or their time spent in) categorized places changes compared to baseline days, which represent a “normal” value for that day of the week. The baseline day is the median value from the five-week period between Jan 3 – Feb 6, 2020, prior to the COVID-19 pandemic. The report provides movement trends in six different categories of places, which are “retail and recreation”, “grocery and pharmacy”, “parks”, “transit stations”, “workplaces” and “residential”. We used “residential” data to represent the effect of governments’ restrictive measures on movement (i.e., lockdown) in 42 countries. A higher percentage indicates more time people (Google users) spent at home, suggesting a greater effect of the restriction policy in that country.

Data for some variables were unavailable from some countries. International Monetary Fund did not provide unemployment data for Saudi Arabia, United Arab Emirates, and Venezuela. The World Bank did not provide Gini index data for Hong Kong, New Zealand, Saudi Arabia, Singapore, and Taiwan. Google Community Mobility Reports

did not provide data for Iran and Russia.



2.3 Statistical analysis

We used the seasonal Autoregressive Integrated Moving Average (ARIMA) model to estimate the expected Google search volume during the COVID-19 pandemic based on pre-pandemic trends. The ARIMA model, commonly used in time series analysis, has three parameters, p , d , and q , where “ p ” represents the order of the autoregressive model, “ d ” represents the degree of differencing, and “ q ” is the order of moving average model; the model is usually expressed as ARIMA (p,d,q). Since the weekly data used in the analysis spanned across years and seasons, we used the seasonal-ARIMA model. Seasonal-ARIMA model has basically the same algorithm as the ARIMA model. It is written as ARIMA(p,d,q)(P,D,Q) m , while “ P ”, “ D ”, and “ Q ” refer to the autoregressive, differencing, and moving average terms for the seasonal part of the ARIMA model, respectively, and “ m ” is the number of periods in each season.

The COVID-19 outbreak started in March 2020 in most countries. Therefore, we used Google Trends data between January 2016 and February 2020 (217 weeks; the pre-pandemic period) to estimate the expected search volume between March 2020 and February 2021 (53 weeks; the pandemic period). We then compared the expected volume with the observed data to determine if there was a change following the COVID-19 outbreak. We defined a “change” in search volume when the observed search volume was outside the 95% confidence intervals of the expected value – there would be an increased search volume if the observed value is above the upper limit of the expected value, and there would be a decreased search volume if the the observed value is below the lower limit of the expected value. This part of the analysis was

conducted using the statistical software package R.



We calculated the number of weeks in which there was a change in Google search volume and then used Spearman correlation to investigate the association between countries' total number of weeks with a change in Google search volume and the following factors during the 53 weeks after the COVID-19 outbreak – GDP growth rate (2020) and the differences in unemployment rates and Gini index in 2019-2020 (i.e., the values in 2020 minus the values in 2019). This part of the analysis was conducted using SPSS.

Last, we calculated the difference between the observed and expected Google search volume during each of the 53 weeks after the COVID-19 outbreak. Then we used random-effects models to investigate the associations of weekly Google search volume difference (observed minus expected) with the weekly COVID-19 confirmed cases rate, the weekly COVID-19 death rate, and the weekly residential mobility change across the 42 study countries. We analyzed the data using the panel data analysis framework by specifying country ($n=42$) as the panel variable (i.e., the random effect in the model) and week ($n=53$) as the time variable using the *xtset* command in Stata. Random-effects models were conducted using the *xtregar* command. *Xtregar* fits the time-series regression models when the disturbance term is first-order autoregressive. We use *rhotype* (*dw*) to compute autocorrelation; *dw* is the default method, which represents the Durbin–Watson *d* statistic. The Durbin Watson (DW) *d* statistic is a test for autocorrelation and it will always have a value between 0 and 4. A value of 2 means that there is no autocorrelation detected in the sample. Values from 0 to less than 2 indicate positive autocorrelation, and values from 2 to 4 indicate negative

autocorrelation. This part of the analysis was conducted using the statistical software package STATA version 15.



Chapter 3 Results

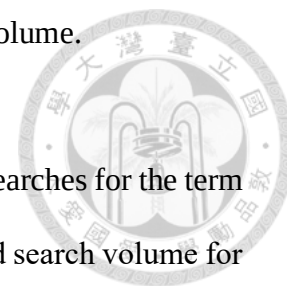
3.1 The changes in weekly Google search volume

Table 1 shows the number of weeks with a change in the search volume of five mental health related terms, “anxiety”, “loneliness”, insomnia”, “depression” and “suicide”, across 42 countries over the 53-week pandemic period investigated. Compared to the expected values, the search volume of the five study terms increased during some weeks in some countries, without any decreases; the only exception was search trends for “depression”, which showed an increase in search volume in some countries and a decrease in others. We calculated the number of weeks with increased search volume for all five terms and additionally the number of weeks with decreased search volume for “depression”.

The mean number of weeks with increased search volume was the highest for the search term “anxiety” (6.86; range 0-37), followed by “insomnia” (5.05; range 0-21), “suicide” (1.57, range 0-10), “loneliness” (1.00; range 0-5), and “depression” (0.67; range 0-5). The mean number of weeks with decreased search volume for “depression” was 3.10 (range 0-16) (Table 1). Figure 2 shows examples of countries with a change in search trends during the COVID-19 pandemic period. Detailed results of changes in search trends across countries were shown in Supplementary Figure 1.

For the search term “anxiety”, some countries, such as Peru, showed increased search volume for most of the study period (Figure 2A). Some countries, such as Brazil (Figure 2B), had consecutive weeks with increased search volume for “insomnia” during the early period of the COVID-19 pandemic. The Netherlands (Figure 2C) had the highest number of weeks with increased search volume for “loneliness” (5 out of 53 weeks),

while about half of the 42 countries showed no changes in search volume.



Few countries (e.g., Mexico Figure 2D) showed increased Google searches for the term “depression”. By contrast, more countries had weeks with decreased search volume for “depression”, which tended to concentrate in the early stage of the pandemic in some countries, such as the US (Figure 2E). Japan showed the highest number of weeks with increased search volume than expected for the term “suicide” (Figure 2F). However, in Japan, the increased search volume for “suicide” appeared to be associated with three celebrity suicides occurring on May 23 (Kimura Hana), July 18 (Kimura Hana), and September 27 (Takeuchi Yūko), 2020.

3.2 The association between increased search volume and socioeconomic variables across countries

Spearman correlation analyses showed that countries’ number of weeks with increased search volume for the term “anxiety” was moderately related to GDP growth rate (negatively) ($\rho = -0.41$; $p=0.006$) and Gini index (positively) ($\rho = 0.42$; $p=0.010$) (Table 2). Similarly, countries’ search volume for “insomnia” was moderately related to GDP growth rate (negatively) ($\rho = -0.36$; $p=0.018$) and Gini index (positively) ($\rho = 0.56$; $p<0.001$), while it additionally showed a strong and positive correlation with the change in the unemployment rate in 2019-2020 ($\rho = 0.60$; $p < 0.001$).

By contrast, search volume for “suicide” showed a moderate negative association with change in the unemployment rate in 2019-2020 ($\rho = -0.38$; $p=0.018$) and Gini index ($\rho = -0.39$; $p=0.018$). No association was found between search volume for “loneliness” or “depression” and any of the variables investigated.



3.3 The association between changes in weekly search volume, residential mobility change, and the severity of COVID-19

Random-effect regression analyses showed that changes (observed minus expected) in weekly search volume for “anxiety”, “loneliness” and “insomnia” were positively associated with residential mobility change over the 53 weeks after the COVID-19 outbreak. A 10% increase in time spent at residential locations was associated with a 0.25%, 0.15%, and 1.01% increase in search volume for “anxiety”, “loneliness”, and “insomnia”, respectively (Table 3). By contrast, a 10% increase in time spent at residential locations was associated with a 0.23 % decrease in search volume for “depression”. No association was found between residential mobility changes and the search volume for “suicide”.

COVID-19 confirmed case rates were positively associated with the search volume for “anxiety” and “depression”. One unit increase in the COVID-19 confirmed case rates (per thousand) was associated with a 1.55 % and 0.77 % increase in search volume for “anxiety” and “depression”, respectively. The COVID-19 mortality rates showed a strong positive association with search volume for “anxiety” and “insomnia”. One unit increase in the COVID-19 mortality rate (per thousand) was associated with a 65.53 % and 64.74 % increase in search volume for “anxiety” and “insomnia”, respectively.

Chapter 4 Discussion

4.1 Main Findings

Changes in the Google search volume of five mental health-related terms (“anxiety”, “insomnia”, “loneliness”, “depression” and “suicide”) showed varying trends across 42

study countries during the first 53 weeks of the COVID-19 outbreak, relative to that expected based on pre-pandemic trends. Searches for “anxiety” had the highest mean number of weeks with increased search volume (6.86), followed by “insomnia” (5.05), “suicide” (1.57), “loneliness” (1.00), and “depression” (0.67). By contrast, searches for “depression” also had a mean number of weeks with decreased search volume of 3.10. Correlation analyses showed that economic downturn and income inequality were associated with searches for “anxiety” and “insomnia”. Regression analyses showed that restriction on movement was associated with increased searches for “anxiety”, “loneliness”, and “insomnia” but decreased search for "depression". The severity of the COVID-19 outbreaks, indicated by rates of confirmed cases or mortality, was associated with increased searches for “anxiety”, “insomnia”, and “depression”.

4.2 Strengths and limitations

There are several strengths of this study. First, the COVID-19 pandemic evolved rapidly in different countries, leading to the difficulty for traditional research designs to collect data simultaneously. The strength of Google trends data is that it could reflect the real-time change in search volume during the COVID-19 pandemic. Besides, since mental health problems are a relatively sensitive and personal topic compared to other health problems, Google trends data might help reduce the social-desirability bias from the traditional study design.

Second, compared to other Google Trends researches that only included a short period of time during the pandemic, we observed a whole year amount of data. This allowed us to understand the long-term effect of the COVID-19 pandemic on the population’s mental health, rather than only the early stage. Besides, we used 217 weeks of data from

2016 to 2020 as our baseline data, which provides a more robust prediction.

Third, there existed a time lag between the time when the government announced restriction policies and the actual implementation. Unlike other research that use specific date to separate pre- and post- lockdown period, we use weekly mobility change data from Google. This method not only helped avoid the time lag mentioned above but also reflected the actual implementation of the restriction policies.

There are several limitations to this study. First, we used Google Trends search data as a proxy of population's mental health status. However, we are not able to know why people searched these terms and under what circumstances. The searching behavior can only reflect people looking for specific information and does not directly mean their real mental health status. We suggested that the relation between the searching behavior of studied search terms and the population's actual mental health status needs to be studied more. Some said that Google Trends data of some search terms is not a helpful indicator to measure the change in population's mental health (Duleeka Knipe, David Gunnell, Hannah Evans, Ann John, & Daisy Fancourt, 2021). Indeed, we also agreed that "suicide" was not an appropriate search term.

Second, although we already chose countries with over 50% internet penetration, the proportion of internet users might not be evenly distributed. The elderly, the young, and those who cannot access the internet; for example, the homeless might be excluded from our data. Also, due to privacy, Google Trends does not provide personal information from searchers, such as gender and age. Thus we were unable to conduct further analysis.



Third, among the COVID-19-related and socioeconomic variables, GDP growth rate, unemployment rate, and Gini index are yearly data, which means these data could not reflect the real-time situation. As for the mobility data from Google Community Mobility Reports, those who are not Google users and those who turned off the “location history” setting were also excluded. Another limitation is that, we are not able to know how Google distinguishes the six categories of places. In some countries, for example, Taiwan, the residential and commercial areas are mixed, and this might affect the accuracy of the mobility data. And lastly, this study is an ecological study, the inferences cannot be made at the individual level.

4.2 The distribution of excess search volume within 53 weeks

The change of the five search terms showed different patterns of distribution within the 53 weeks, suggesting that people might be facing different kinds of mental health distress in different stages of the pandemic. Among the five search terms, “anxiety” had the most weeks with increased search volume and the most difference in search volume (observed minus expected) within the 53 weeks. This result indicated that searching for anxiety-related information might be a common reaction people presented during the COVID-19 pandemic; a review study also supported the relationship between the pandemic and anxiety symptoms (Machado et al., 2020).

Besides, we noticed that the search volume of “anxiety” increased densely during the early stage of the study period in some countries, such as Brazil, Colombia, Indonesia, Mexico and the Philippines. This result was also shown in other Google Trends studies, but in different countries. A study found that anxiety queries were cumulatively 11%

higher than expected for about two months after the United States president declared a national emergency on March 13, 2020, which was the relatively early stage of the pandemic (Ayers et al., 2020). Another study also used Google Trends database and found that people's reactions during the pandemic can be divided into different stages (Hoerger et al., 2020). In the beginning, Google searches related to "worry" and "panic" showed a temporary increase after the pandemic declaration. Later, the worry turned into increases in clinical symptoms, such as "anxiety symptoms" and "anxiety attack". These results were consistent with our finding that anxiety might be the early reaction people presented during the COVID-19 pandemic.

However, not every country presented this pattern. There were a couple of explanations. First, the way people react to the pandemic might vary across countries due to the difference in culture, religion, health system, or even political system (Furlong & Finnie, 2020; Mashaphu, Talatala, Seape, Eriksson, & Chiliza, 2021). Second, the COVID-19 outbreak occurred to different countries at different times. For example, Spain and Italy were already facing severe impacts of COVID-19 in late February 2020, but countries like Taiwan and New Zealand were still relatively stable at that time. Thus, it is reasonable that the increases in the search term "anxiety" are present at different times during the study period. This leads to the third explanation, in the very beginning of the pandemic, most countries have not developed mature response strategies to the pandemic of all time. People from countries that faced the COVID-19 outbreak earlier might react more intensively.

The increase of "insomnia" was slightly less than "anxiety", but the increases were still worth paying attention to. The previous study also found that the worldwide "insomnia"

search queries were significantly greater than before during the pandemic (Lin et al., 2023). Besides, other relative search terms such as “sleep apnea,” “restless legs syndrome,” and “narcolepsy” were also higher than before (Zitting et al., 2021), indicating that sleep problems should not be neglected during the pandemic. We noticed that the increases appear more in the early stage in some countries, such as Brazil, Chile, Colombia, Indonesia, Mexico, the Philippines, and Spain, these countries were facing severe situations indeed (Burki, 2020), and another study also supported that participants from Latin America reported the lowest sleep health scores during the pandemic (Yuksel et al., 2021).

For the search term “loneliness”, half of the 42 studied countries showed increased search volume in some weeks. Previous studies also found that the search volume of “loneliness” increased in Western European countries and the US. (Brodeur, Clark, Flèche, & Powdthavee, 2020) A study suggested that the term “loneliness” could be an indicator of population’s mental health during a public health emergency (D. Knipe, D. Gunnell, H. Evans, A. John, & D. Fancourt, 2021). During the pandemic, isolation and loneliness have always been a threat to mental health. Moreover, it is related to the behavior of self-harm, especially those who live alone (Hawton et al., 2021). Although the increase did not show as much as the search terms “anxiety” and “insomnia”, we suggested that loneliness is still an issue that should be paying attention to during the pandemic.

The search term “depression” presented unexpected results; most countries showed decreased rather than increased search volume during the study period. There was a study conducted in the UK that found consistent results with us (Knipe et al., 2020).

But other studies indicated no change in the search term “depression” in the US and Latin America (Sinyor et al., 2020; Tirado, Hoehn-Velasco, Miyar, & Silverio-Murillo, 2020). The total weeks of decreased search volume were 4.6 times more than increased search volume; what is worth taking note of is that the decreases mostly happened in the early stage of the study period. This pattern can be found in France, Germany, Poland, Spain, the UK, and the US. A longitudinal study found that depressive symptoms significantly decreased following the lockdown in the UK (Fancourt et al., 2021). An explanation for these findings is that during the stay-at-home periods, people had the chance to spend more time with others and connect with others in new ways; the feeling of “we are all in this together” might help people undergo the gloominess in the early stage of pandemic (Pirkis et al., 2021). We speculated that during the pandemic, people might feel anxious, panic, or even start to have insomnia symptoms; these were natural reactions to stressful circumstances (Sinyor et al., 2020). But gradually, people adapted to the circumstances, and their depression levels declined (Fancourt et al., 2021).

For the search term “suicide”, there was not too much increase during the 53 weeks in most of the studied countries. A study analyzed data from 21 countries found that suicide cases remained unchanged in high-income and upper-middle-income countries in the early months of the pandemic (Pirkis et al., 2021). These results suggest that the mental health impact of the pandemic did not appear to translate into increases in suicides, at least during the study period and in the study countries. However, we noticed that the search volume of some countries was heavily affected by media reports of celebrity suicides, for example, in Japan. We suggest that the keyword “suicide” might not be a suitable search term. Previous studies had used other search terms such

as “suicide methods”, “How to commit suicide” and “How to kill myself” (Sinyor et al., 2020). These search terms might be more suitable than the single search term “suicide” for two reasons. First, they reflected the searcher’s real search intention. Second, they were free from being affected by celebrity suicides. However, the problem with these search terms is that they were unable to generate enough data on Google Trends since the search volume was too low. We suggest that another way to understand a searcher’s suicide intention could be using specific suicide methods such as “hanging”, “charcoal burning”, “sleeping pills” and “firearms” (Halford, Lake, & Gould, 2020).

4.3 Association of Google search volume and potential factors across countries

The Spearman correlation showed that the weeks with an increased search volume of both “anxiety” and “insomnia” were negatively associated with the 2020 GDP growth rate. In other words, countries with higher GDP growth rates had fewer weeks of increased search volume, and countries with lower GDP growth rates had more weeks of increased search volume. We also found that the weeks with an increased search volume of “insomnia” were positively associated with the difference in the unemployment rate (2020-2019). Based on our findings, it is possible that the worsening economy and poor job market of a country are potential factors that lead to population negative mental health outcomes. In 2020, most countries had a negative GDP growth rate due to the COVID-19 pandemic. A study indicated that service-oriented economies, for example, Spain, which relies on tourism very much, were particularly negatively affected (Fernandes, 2020). It is important that government react rapidly to stabilize the economy and give support to those who face financial problems during the pandemic.

Besides, the weeks with an increased search volume of “anxiety” and “insomnia” were also positively associated with countries’ Gini index. This result indicated that people who live in countries with more significant inequality of wealth might have a higher risk of mental health problems. Income inequality is a powerful driver of mental health (Burns, 2015). Previous studies also indicated that the negative effect of unemployment on mental health was stronger in countries with unequal income distributions than in countries with more equal income distributions (Paul & Moser, 2009). During the pandemic, the inequality issue has raised many discussions. People of low socio-economic status (SES) not only had a higher chance of getting infected but also were more vulnerable to mental health due to their financial uncertainty (Patel et al., 2020). We suggested that reducing inequality is also an important task that government should take care of during the pandemic.

Results from the random-effects model showed that there existed positive correlations between the COVID-19 death rate and the increased search volume of “anxiety” and “insomnia”, indicating the severity of COVID-19 had a direct effect on the population’s mental health. Also, there were positive correlations between the time spent at home and the search volume of “anxiety”, “insomnia” and “loneliness”; however, the search term “depression” presented an opposite correlation. There were debates about whether lockdown measures improve or worsen the population’s mental health. A study found that both the search volume of “anxiety” and “insomnia” levelled off following the issuance of stay-at-home orders in the US, pointed out that the announcement of stay-at-home orders might prevent fears and unrest during the pandemic (Jacobson et al., 2020). But other studies indicated that the stronger restrictions during the lockdown, the greater reduction of social contacts, and the greater perceived changes in life were

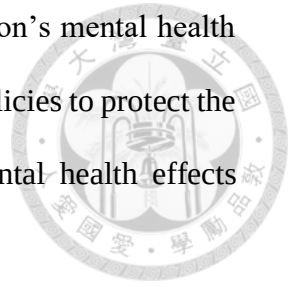
associated with severe mental health impairments (Benke, Autenrieth, Asselmann, & Pané-Farré, 2020). We conclude that the implementation of restriction policies might immediately relieve the population's worries and tension, but based on our findings, the long-term effects on mental health should be discussed. Besides, it is possible that the effect of the lockdown caused a different impact in different countries due to the way government implements these policies (Kumar, Priya, & Srivastava, 2021). Also, the effect on different populations was also uneven. For example, a study found that both anxiety and depressive symptoms declined across the first 20 weeks following the lockdown in England; however, the amplitudes of decline were different between different gender, education levels, and living styles (alone or with others) (Fancourt et al., 2021).

Chapter 5 Conclusion

This study examined five mental health-related terms from Google Trends data as an indicator for population mental health during the COVID-19 pandemic (March 2020-February 2021) and their associations with the severity of the pandemic, population mobility changes, and economic variables in 42 countries. During the worldwide public health emergency, Google Trends data could be another tool to understand the change in population's mental health, but we suggested that the choice of search terms should be fully discussed.

In conclusion, this study suggests that anxiety and insomnia might be the mental health symptoms that should be carefully noticed during the COVID-19 pandemic. Although restriction policies helped control the outbreak, governments should be alert to the negative mental health effect on people. Economic factors, such as unemployment and

wealth inequality within a country, might also worsen the population's mental health status; we suggested that governments should implement relative policies to protect the vulnerable group and keep being vigilant to the longer-term mental health effects caused by pandemic.



Figure

Figure 1. The distribution of the 42 study countries.

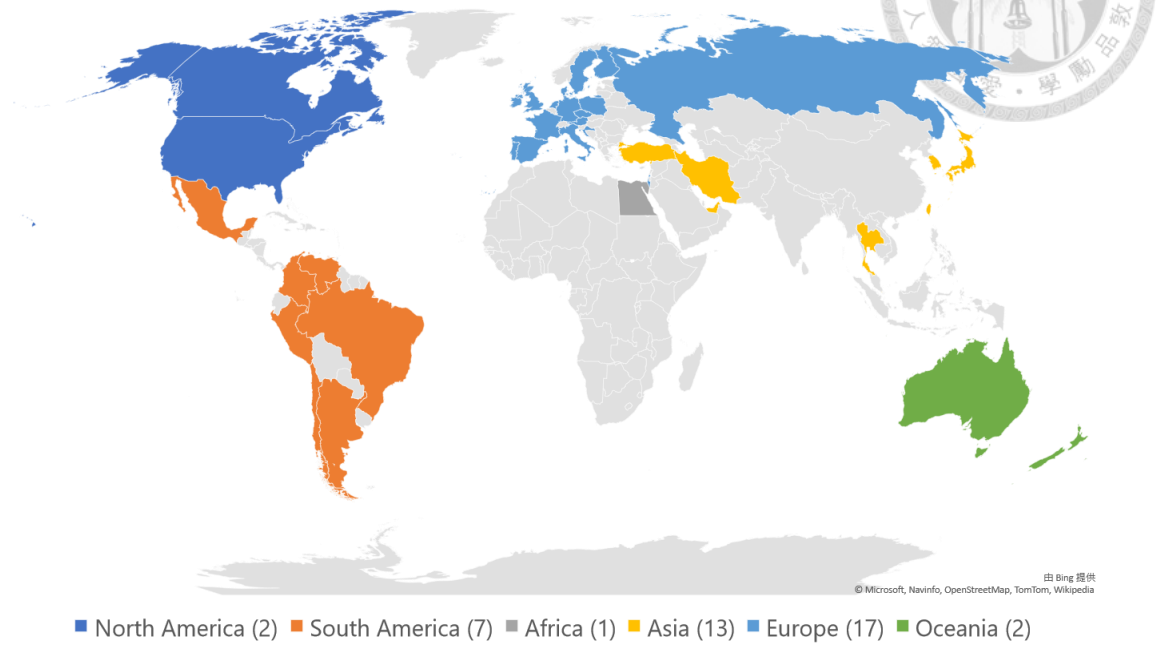
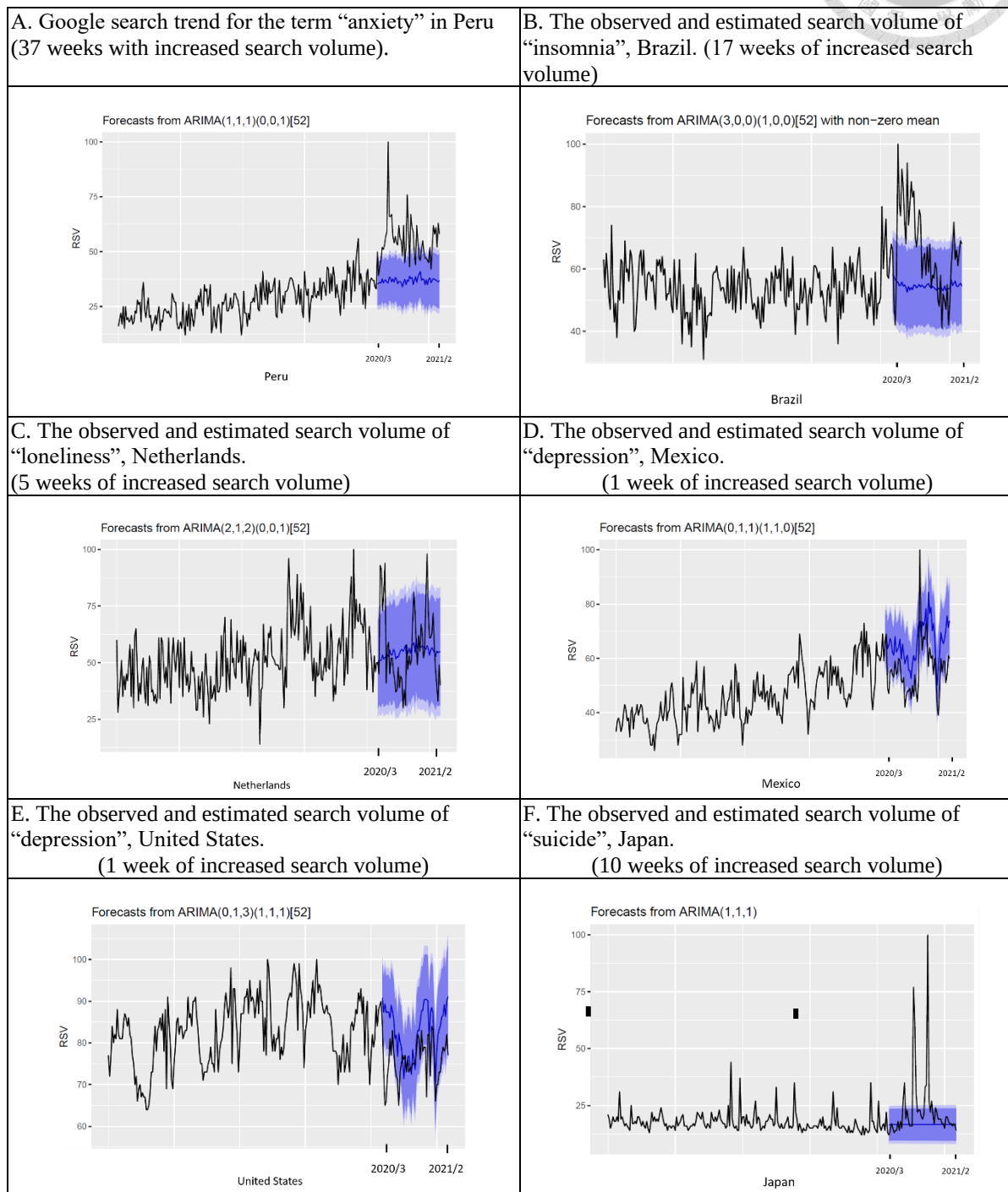


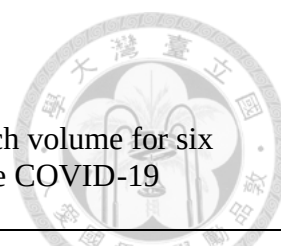
Figure 2. Examples of Google search trends for mental health related terms during the pre-pandemic (Jan 2016-Feb 2020) and pandemic (Mar 2020-Feb 2021) periods and expected values based on pre-pandemic data, estimated using the autoregressive integrated moving average (ARIMA) model, during the pandemic period in selected countries.



Note: The black line indicates the observed weekly search volume extracted from Google Trends between Jan 2016 and Feb 2021 (270 weeks). The blue line indicates the expected search volume from the ARIMA models during Mar 2020-Feb 2021 (53 weeks), with 90% (purple) and 95% (light purple) confidence intervals. Observed search volume that was outside the 95% confidence intervals of expected values was regarded as evidence for a change in search volume during the pandemic period.

Table

Table 1. The number of weeks with increased or decreased Google search volume for six mental health related terms across 42 countries over 53 weeks during the COVID-19 pandemic period (Mar 2020-Feb 2021).



Country	Anxiety		Insomnia		Loneliness		Depression		Depression		Suicide	
	Number of weeks with increased search volume in RSV (N)	Rank	Number of weeks with increased search volume in RSV (N)	Rank	Number of weeks with increased search volume in RSV (N)	Rank	Number of weeks with increased search volume in RSV (N)	Rank	Number of weeks with decreased search volume in RSV (N)	Rank	Number of weeks with increased search volume in RSV (N)	Rank
Argentina	10	10	3	20	1	13	3	2	6	7	0	34
Australia	0	31	7	11	2	4	0	17	2	17	5	3
Austria	0	31	2	25	4	3	0	17	0	28	2	7
Brazil	14	8	17	2	2	4	0	17	0	28	2	7
Canada	0	31	4	17	5	1	0	17	5	8	1	14
Chile	4	20	8	9	0	23	0	17	1	21	1	14
Colombia	15	6	10	6	1	13	1	9	3	15	0	34
Croatia	3	23	3	20	0	23	0	17	0	28	2	7
Czech	2	26	6	15	2	4	0	17	1	21	3	5
Denmark	0	31	1	34	2	4	0	17	3	15	1	14
Egypt	1	30	2	25	2	4	0	17	2	17	1	14
Finland	0	31	2	25	0	23	0	17	4	12	1	14
France	5	16	0	38	2	4	0	17	5	8	1	14
Germany	15	6	1	34	2	4	0	17	8	5	1	14
Hong Kong	2	26	4	17	1	13	1	9	0	28	0	34
Indonesia	3	23	16	3	0	23	1	9	0	28	0	34
Iran	4	20	2	25	0	23	0	17	0	28	3	5
Ireland	3	23	0	38	0	23	0	17	1	21	1	14
Israel	0	31	2	25	1	13	0	17	5	8	0	34
Italy	22	4	1	34	0	23	2	3	5	8	0	34
Japan	5	16	3	20	0	23	2	3	1	21	10	1
Korea	6	14	2	25	0	23	1	9	0	28	2	7
Malaysia	2	26	8	9	0	23	0	17	0	28	1	14
Mexico	18	5	14	4	0	23	1	9	16	1	1	14
Netherlands	9	11	0	38	5	1	2	3	0	28	1	14
New Zealand	5	16	2	25	1	13	2	3	0	28	1	14
Peru	37	1	11	5	1	13	1	9	4	12	1	14
Philippines	35	2	21	1	0	23	0	17	0	28	0	34
Poland	0	31	2	25	1	13	1	9	16	1	2	7
Portugal	7	13	3	20	1	13	0	17	1	21	4	4
Russia	4	20	0	38	0	23	2	3	4	12	2	7
Saudi Arabia	0	31	10	6	0	23	0	17	1	21	1	14
Singapore	12	9	7	11	2	4	0	17	0	28	0	34

Spain	23	3	9	8	1	13	1	9	8	5	0	34
Sweden	0	31	2	25	0	23	0	17	0	28	1	14
Thailand	0	31	1	34	1	13	0	17	2	17	1	14
Turkey	9	11	4	17	0	23	0	17	1	21	1	14
Taiwan	2	26	0	38	0	23	2	3	0	28	2	7
United Arab Emirates	6	14	5	16	0	23	5	1	0	28	7	2
UK	0	31	3	20	0	23	0	17	14	3	1	14
United States	0	31	7	11	0	23	0	17	9	4	1	14
Venezuela	5	16	7	11	2	4	0	17	2	17	1	14
Mean	6.86		5.05		1.00		0.67		3.10		1.57	
Median	4		3		1		0		1		1	
Range (min, max)	(0,37)		(0,21)		(0,5)		(0,5)		(0,16)		(0,10)	

Note: RSV: relative search volume in Google.

Table 2. Spearman correlations between the number of weeks with increased Google search volume for the keywords “anxiety”, “loneliness”, “insomnia”, “depression”, and “suicide” (and with decreased Google search volume for “depression”) and socioeconomic variables across countries during the COVID-19 pandemic (Mar 2020-Feb 2021).

	rho	95% confidence interval	p-value	Number of countries
Anxiety				
2020 GDP growth rate	-0.41	(-0.65 , -0.11)	0.006	42
Change in unemployment rate between 2019-2020	0.12	(-0.21 , 0.42)	0.48	39
Gini index	0.42	(0.10 , 0.66)	0.010	37
Loneliness				
2020 GDP growth rate	-0.14	(-0.43 , 0.17)	0.37	42
Change in unemployment rate between 2019-2020	-0.03	(-0.35 , 0.28)	0.83	39
Gini index	-0.18	(-0.48 , 0.16)	0.30	37
Insomnia				
2020 GDP growth rate	-0.36	(-0.61 , -0.06)	0.018	42
Change in unemployment rate between 2019-2020	0.60	(0.33 , 0.78)	<0.001	39
Gini index	0.56	(0.26 , 0.76)	<0.001	37
Depression (weeks of increased Google search volume)				
2020 GDP growth rate	-0.07	(-0.37 , 0.24)	0.65	42
Change in unemployment rate between 2019-2020	-0.01	(-0.32 , 0.31)	0.96	39
Gini index	0.02	(-0.31 , 0.34)	0.92	37
Depression (weeks of decreased Google search volume)				
2020 GDP growth rate	-0.25	(-0.52 , 0.06)	0.11	42
Change in unemployment rate between 2019-2020	0.03	(-0.29 , 0.35)	0.84	39
Gini index	0.16	(-0.18 , 0.46)	0.35	37
Suicide				
2020 GDP growth rate	0.26	(-0.06 , 0.52)	0.102	42
Change in unemployment rate between 2019-2020	-0.38	(-0.63 , -0.06)	0.018	39
Gini index	-0.39	(-0.64 , -0.06)	0.018	37

Correlation coefficients, 95% confidence intervals, and p values are shown in bold when p values are <0.05.

Table 3. Random-effects regression analysis: the associations between weekly Google search volume for five mental health related terms, Google residential mobility changes, and the rates of COVID-19 confirmed cases and deaths across 42 countries

Variable	Coefficient	95 % confidence interval	p-value
Anxiety			
Google residential mobility change/10	0.25	(0.13 , 0.38)	<0.001
COVID-19 confirmed case rate*1000	1.55	(1.01 , 2.09)	<0.001
COVID-19 death rate*1000	65.53	(37.58 , 93.47)	<0.001
Loneliness			
Google residential mobility change/10	0.15	(0.01 , 0.29)	0.034
COVID-19 confirmed case rate*1000	-0.24	(-0.88 , 0.40)	0.458
COVID-19 death rate*1000	12.34	(-20.54 , 45.23)	0.462
Insomnia			
Google residential mobility change/10	1.01	(0.86 , 1.16)	<0.001
COVID-19 confirmed case rate*1000	0.55	(-0.23 , 1.33)	0.169
COVID-19 death rate*1000	64.74	(25.18 , 104.29)	0.001
Depression			
Google residential mobility change/10	-0.23	(-0.35 , -0.12)	<0.001
COVID-19 confirmed case rate*1000	0.77	(0.25 , 1.30)	0.004
COVID-19 death rate*1000	9.13	(-18.12 , 36.38)	0.511
Suicide			
Google residential mobility change/10	-0.06	(-0.15 , 0.04)	0.239
COVID-19 confirmed case rate*1000	-0.16	(-0.59 , 0.27)	0.463
COVID-19 death rate*1000	-5.91	(-28.17 , 16.35)	0.603

Regression coefficients, 95% confidence intervals, and p values are shown in bold when p values are <0.05.

Supplementary materials

Supplementary Table 1. Translation of the six mental health related terms in 42 countries.

Country	anxiety	loneliness	insomnia	depression	suicide
Argentina	ansiedad	soledad	insomnio	depresión	suicidio
Austria	angst	einsamkeit	schlaflosigkeit	depression	Selbstmord
Australia	anxiety	loneliness	insomnia	depression	suicide
Brazil	ansiedade	solidão	insônia	depressão	suicídio
Canada	anxiety	loneliness	insomnia	depression	suicide
Chile	ansiedad	soledad	insomnio	depresión	suicidio
Colombia	ansiedad	soledad	insomnio	depresión	suicidio
France	anxiété	solitude	insomnie	dépression	suicide
Germany	angst	einsamkeit	schlaflosigkeit	depression	Selbstmord
Hong Kong	焦慮	孤獨	失眠	憂鬱	自殺
Indonesia	cemas	kesendirian	insomnia/tidak bisa tidur	depresi	bunuh diri
Iran	بارظا	فردگي روغتيا	بى اوخ بى	بى درنيا	ن دىک بى دى دى دى
Italy	ansia	solitudine	insonnia	depressione	Suicidio
Japan	不安	孤独	不眠	鬱	自殺
Korea	불안장애	외로움	불면증	우울증	자살
Malaysia	anxiety	kesunyian	insomnia	depression	membunuh diri
Mexico	ansiedad	soledad	insomnio	depresión	suicidio
Netherlands	angst	eenzaamheid	slapeloosheid	depressie	zelfmoord plegen
New Zealands	anxiety	loneliness	insomnia	depression	suicide
Peru	ansiedad	soledad	insomnio	depresión	suicidio
Philippines	anxiety	kalungkutan	insomnia	depresyon	pagpapatiwakal
Poland	lęk	samotność	bezsenność	depresja	samobójstwo
Portugal	ansiedade	solidão	insônia	depressão	suicídio
Russia	тревожност ь	одиночеств о	бессонница	депрессия	самоубийство
Saudi Arabia	قلق	فردگي روغتيا	قربا	بى درنيا	را بى دى
Singapore	anxiety	loneliness	insomnia	depression	suicide
Spain	ansiedad	soledad	insomnio	depresión	suicidio
Sweden	ångest	ensamhet	sömnlös	depression	självmoord
Taiwan	焦慮	孤独	不眠	鬱	自殺
Thailand	ความวิตกกังวล	ความเหงา	นอนไม่หลับ	ภาวะซึมเศร้า	การฆ่าตัวตาย
Turkey	kaygı	yalnızlık	uykusuzluk	depresyon	intihar
United States	anxiety	loneliness	insomnia	depression	suicide
United Kingdom	anxiety	loneliness	insomnia	depression	suicide
Croatia	anksioznost	usamljenost	nesanica	depresija	samoubojstvo
Czech	úzkost	osamělost	nespavost	deprese	spáchat sebevraždu
Denmark	angst	ensomhed	insomnia	depression	selvmord
Egypt	قلق	فردگي روغتيا	قربا	بى درنيا	را بى دى
Finland	ahdistus	yksinäisyys	unettomuus	masennus	itsemurha
Ireland	anxiety	loneliness	insomnia	depression	suicide
Israel	חרדה	בדידות	היפסיד	דכאון	התאבדות
United Arab Emirates	قلق	فردگي روغتيا	قربا	بى درنيا	را بى دى
Venezuela	ansiedad	soledad	insomnio	depresión	suicidio

Supplementary Figure 1. The distribution of weeks with increased (or decreased) Google search volume for five mental health related terms in 42 countries over 53 weeks during the COVID-19 pandemic period (Mar 2020-Feb 2021).

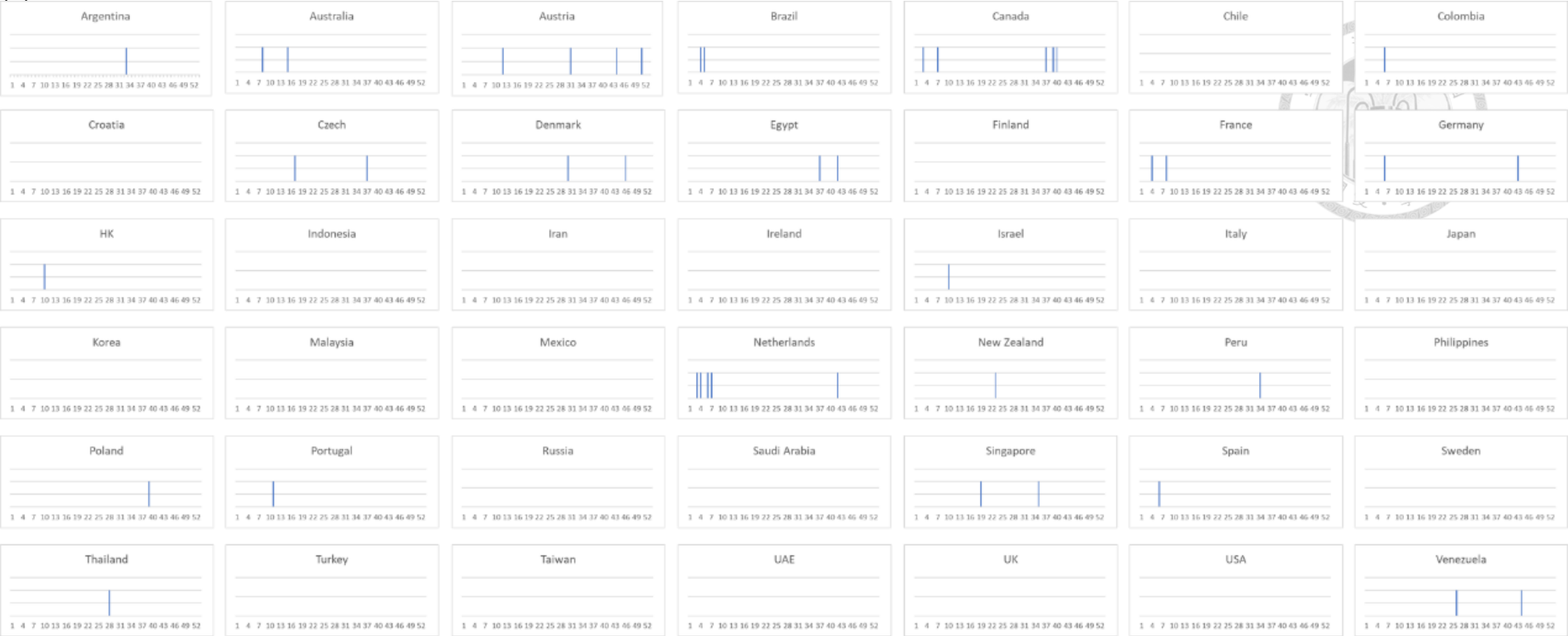
(A) “Anxiety”



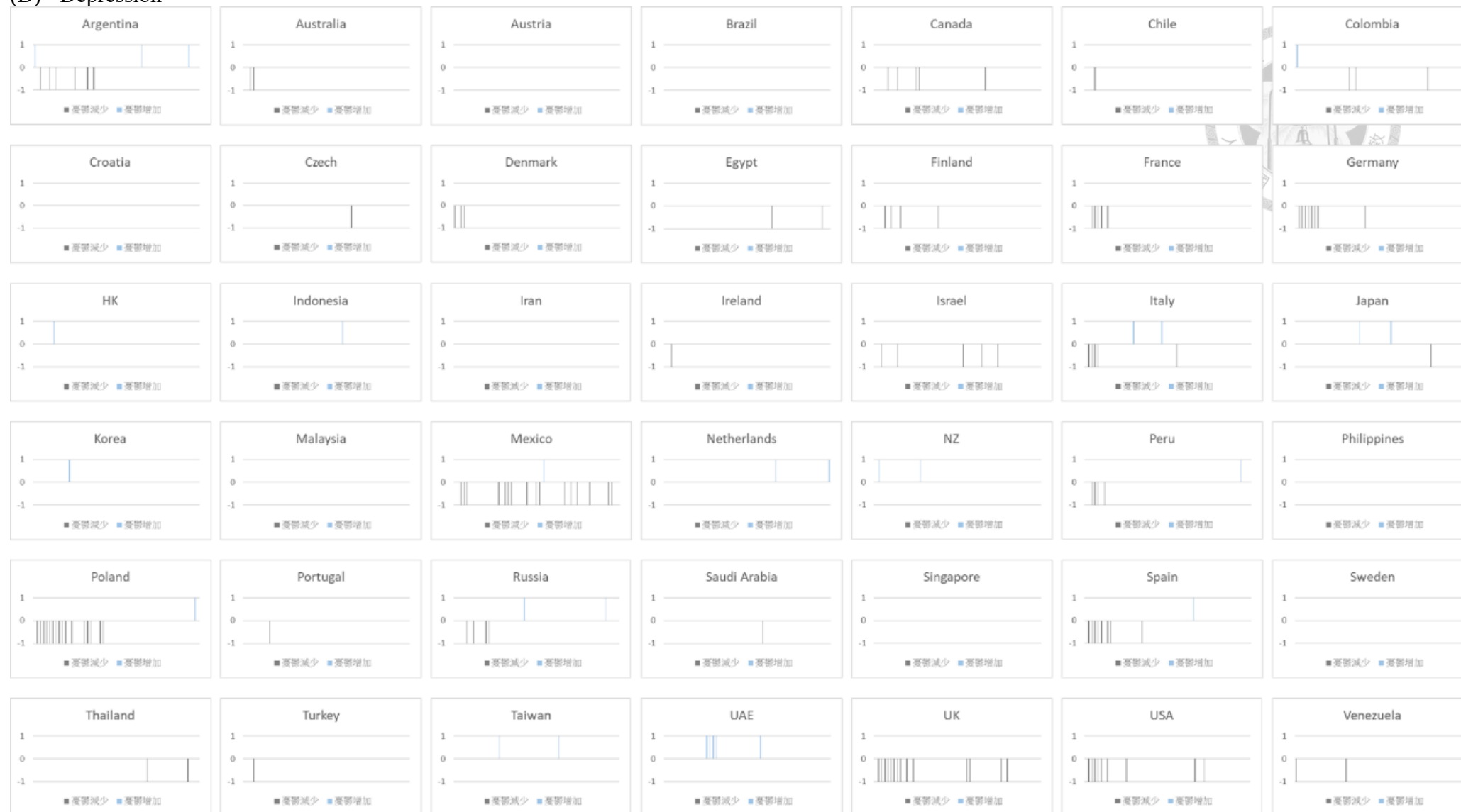
(B) “Insomnia”



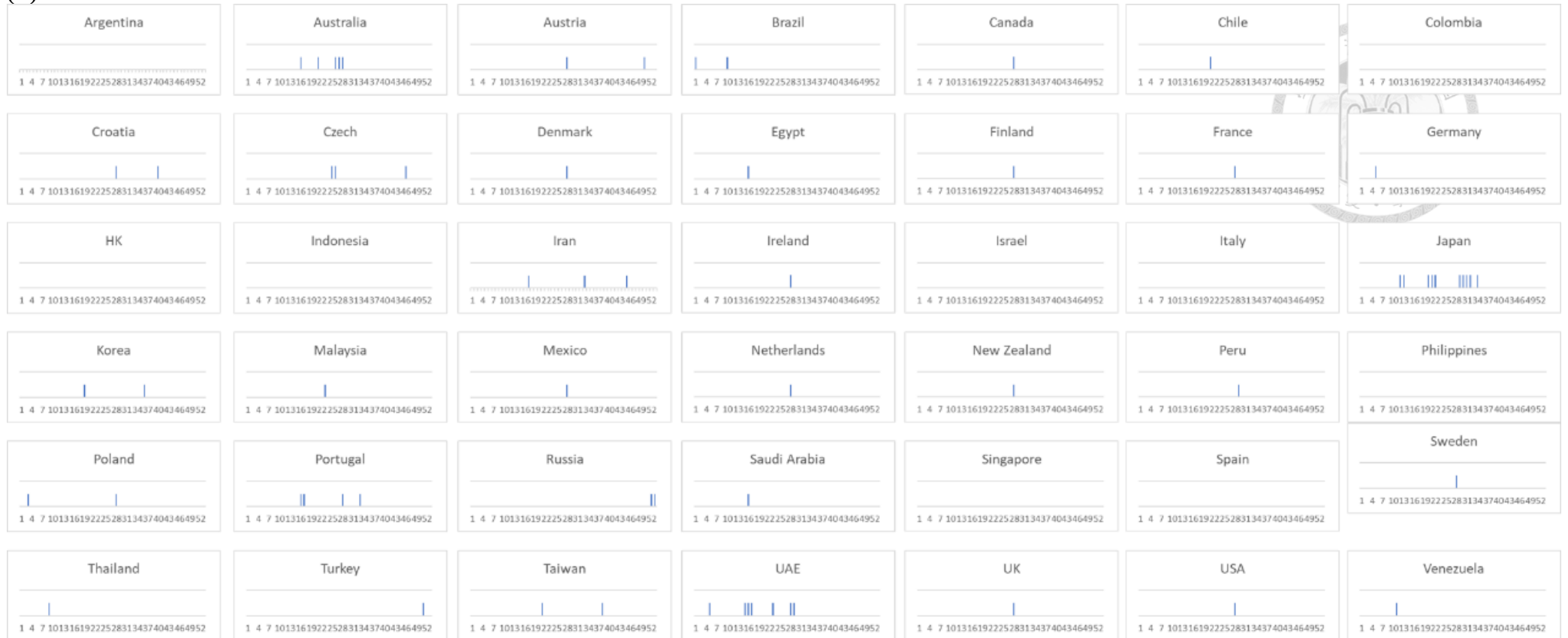
(C) “Loneliness”



(D) “Depression”



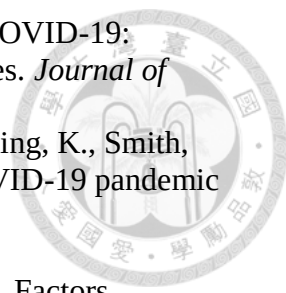
(E) “Suicide”



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