Comparative Study of Government Response Measures and Epidemic Trends for COVID-19 Global Pandemic

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The ongoing novel coronavirus (COVID-19) epidemic has evolved into a full range of challenges that the world is facing. Health and economic threats caused governments to take preventive measures against the spread of the disease. This study aims to provide a correlation analysis of the response measures adopted by countries and epidemic trends since the COVID-19 outbreak. This analysis picks 13 countries for quantitative assessment. We select a trusted model to fit the epidemic trend curves in segments and catch the characteristics based on which we explore the key factors of COVID-19 spread. This review generates a score table of government response measures according to the Likert scale. We use the Delphi method to obtain expert judgments about the government response in the Likert scale. Furthermore, we find a significant negative correlation between the epidemic trend characteristics and the government response measure scores given by experts through correlation analysis. More stringent government response measures correlate with fewer infections and fewer waves in the infection curves. Stringent government response measures curb the spread of COVID-19, limit the number of total infectious cases, and reduce the time to peak of total cases. The clusters of the results categorize the countries into two specific groups. This study will improve our understanding of the prevention of COVID-19 spread and government response.

KEY WORDS: Correlation analysis; COVID-19; emergency response; epidemic trend

1. INTRODUCTION

Since the outbreak of COVID-19, various countries have suffered from peaks of confirmed cases, which have caused great harm to public health and have brought huge economic losses. Various countries have adopted different measures in response to the epidemic. The focus and implementation of the measures have been changing over time. Epidemic trends in the countries have shown differences (Smith, 2020; Roda et al., 2020). New confirmed cases are still at a relatively high level in many countries around the world, as observed through February 20, 2021 (Barmparis & Tsironis, 2020).

Historically, major pandemics have had a huge impact on human society each time, such as SARS in 2003, H1N1 in 2009, Ebola in 2014 and 2019 (Coltart, Lindsey, Ghinai, Johnson, & Heymann, 2017; Martinez-Alvarez et al., 2020). Study on epidemics is abundant and involves various aspects. Research at the macro level generally uses the SIR model and its related models such as the Susceptible-Infected-Recovered Model, the Susceptible-Exposed-Infected-Recovered Model, the Susceptible-Infected-Susceptible Model, the Susceptible-Infected-Recovered-Susceptible Model, the Susceptible-Exposed-Infected-Recovered-Susceptible Model, the Susceptible-Infected-Recovered-Infected Model, the Seasonal-Auto-Regressive-Integrated Moving Average Model to
simulate and predict the spread trend of a country (Chen, Liu et al., 2020) or around the world, evaluate the risk and consequences of the spread of the epidemic, and give corresponding policy recommendations (Ma, Bisset, Chen, Deodhar, & Marathe, 2011). Evaluation methods include information entropy models, spatial-scale infectious disease models, and big data analysis without a certain model. Methods have gradually transitioned from qualitative evaluation to quantitative evaluation that relies on sufficient data. Some researchers have explored the spreading laws of the epidemic and key infectious factors obtained by the controlled variable method through the above infectious disease models (Villela, 2020). At the same time, subregional research focusing on dynamic networks and scale-free networks with community structures (Xu et al., 2019) has gradually become a hot spot. Through the combination of numerical methods and epidemic models, they explore the impact of key factors such as gathering behaviors and vaccination effects on the epidemic among single, overlapping (Shang, Liu, Xie, & Wu, 2014), and dynamic communities (Weia, Gui-hongb, & Zhang, 2012). The spread of panic and other negative emotions in an epidemic is generally based on the study of personal speech, relying on neural networks and deep learning data processing methods to mine the available open data and use dynamics model analysis (Li, Jiang, & Song, 2016). These studies rarely consider the relationship between epidemic trends and government response measures at the country level. Therefore, this article aims to quantitatively explore the relationship between them.

For the epidemic prevention measures, many articles classify them according to cultural, economic, environmental, and other factors (Shokouhyar, Shokoohyar, Sobhani, & Gorizi, 2021). This article divides them from a new perspective from micro to macro. We can roughly summarize the government response measures adopted by countries against COVID-19 into four levels, such as country, city, community, and individuals. Nevertheless, policies are different due to different economic conditions, cultures, and human behaviors.

At the country level, various governments face the challenge of the rapid geographic spread of the pandemic (Li et al., 2020). Important measures include strict border control (Fang, Nie, & Penny, 2020), detection of imported commodities, rapid monitoring and patient finding, rapid case reporting, rapid quarantine of suspected and confirmed cases, rapid detection of the Nucleic Acid of coronavirus, fast and early treatment of confirmed cases (Ren et al., 2020; Wein & Atkinson, 2009; Tang et al., 2020), guaranteed supply of medicine and protective appliances (Omori, Mizumo, & Chowell, 2020), effective contact tracing (Anderson, Heesterbeek, Klinkenberg, & Hollingsworth, 2020; Ma, 2020), risk analysis and risk communication, a high priority of vaccines development and application (Thompson & Duintjer Tebbens, 2016), collaboration with other countries and international organizations (Corey, Mascola, Fauci, & Collins, 2020), and local government, community, and organization support (Salje et al., 2020).

At the city level, a series of measures including lockdown (Ivanov, 2020), travel bans, a shutdown of businesses such as cinemas and theaters, cancellation of bars and parties, cancellation of other mass gatherings, school closure, closing workplace (García-Basteiro et al., 2020), implementing personnel control measures in the shopping center (Lewnard & Lo 2020; Scarabel, Pellis, Bragazzi, & Wu, 2020) are launched. Policymakers should base decisions on hospital controlled measures (Adalja, Toner, & Inglesby, 2020; Anderson, Turnham, Griffin, & Clarke, 2020; Rosoff, John, & Prager, 2012), the opening of fever clinics (Brindle & Gawande, 2020; Her, 2020) evaluation of the economic problems caused by the epidemic (Erikson & Johnson, 2020; Yu & Aviso, 2020), attempts to ensure the supply of daily necessities (Ranney, Griffeth, & Jha, 2020), usage of reliable surveillance platforms (Mello & Wang, 2020), application of digital epidemiology (Azizi et al., 2020), maintaining the public’s trust (Chandrashekar et al, 2020), guaranteeing social security. These measures also have been effective in mitigating the transmission of COVID-19.

At the community level, high susceptibility is the main driver (Robertson, 2019). The controlled measures including curbing population flows, access control, body temperature monitoring, use of health codes, reduction of unnecessary contact, implementing the combined intervention in quarantining infected individuals and their family members once transmission has been detected, regular disinfection, reinforce propaganda, and education could substantially reduce the number of COVID-19 infections (Li, Bi et al., 2020; Tay, Poh, Rénia, MacAry, & Ng, 2020; Zagmutt, Schoenbaum, & Hill, 2016). Guarantee of community service and social innovation of hospitals by the power of local supporters are also essential (Halpaap et al., 2020; López-García, King, & Noakes, 2019; Smith, 2020).
At the individual level, the epidemics prevention and control measures include social distancing measures, self-isolation, wearing personnel protection equipment such as medical masks and glasses (Leung et al., 2020; Livingston, Desai, & Berkwits, 2020), performing hand hygiene frequently, avoiding touching eyes, nose, and mouth (World Health Organization, 2020), attempts to ensure room ventilation, maintaining environmental hygiene including avoiding direct contact with door handles and elevator buttons, handling hazardous waste (Vinarti & Hederman, 2019). To protect yourself from digital contact tracing apps or a personalized infectious disease risked prediction system is also recommended (Caicedo-Ochoa, Rebellón-Sánchez, Peñaloza-Rallón, Cortés-Motta, & Méndez-Fandiño, 2020; Govindan, Mina, & Alavi, 2020; Yan et al., 2020).

We can evaluate the implementation of government response measures to the epidemic comprehensively by considering both the policy proposal of the government and the degree of public cooperation through the above summary. We evaluate the epidemic situation in countries by quantitative parameters, which are obtained through fitting a suitable function to the epidemic trend curves of the countries. This article intends to explore the relationship between the strictness of government response measures obtained through the assessment and the epidemic trend characteristics by simulation of different countries.

2. METHOD

2.1. Simulation of Epidemic Trends

The outbreak location of COVID-19 was single when it first occurred in a country, and then the number of locations increased over time. Characteristics for the growth of confirmed cases in each outbreak site are coupled into the overall epidemic curve. Therefore, we use the segmented method to fit the epidemic trend curves of countries. There are many methods of curve fitting, including the SIR model, SEIR model, Gaussian equation, and others. They describe epidemic dynamics simply, so the shapes of the models are too regular to fully reflect the law of the epidemic curves. Recently we find that the epidemic renormalization group (e-RG) approach is put forward to discuss the trends of pandemic (Della Morte et al., 2020). The e-RG model is inspired by particle physics methodologies. It achieves a better understanding of the infection rate by considering the recovered cases appropriately. It has better stability because of the shape of the equation with longer tailing and asymmetry. And it can be transformed with the SIR model. The e-RG model uses the logarithm of the total number of confirmed cases and the time per week as dependent and independent variables, respectively.

\[
\alpha(t) = \ln I(t),
\]

\(\alpha\) is the logarithm of total confirmed cases; \(I\) is the total confirmed cases.

It provides a microscopic model of the infection rate. It governs the dependence of inverse energy in statistical and high energy physics and regulates infectious interactions here.

\[
y(\alpha) = -\frac{da}{d\ln(u/u_0)} = -\frac{da}{dt}
\]

It identifies the time as \(t/t_0 = -\ln u/u_0\), where \(u\) is the energy in high energy physics, \(u_0\) is the energy scale. We choose \(t_0\) to be one week and drop it when time is measured in weeks. The equation can be proposed as (3) when confirmed cases exist in a separate region.

\[
y(\alpha) = \beta\alpha(1 - \alpha/a)^n,
\]

\(\beta\) is the diffusion slope; \(a\) is the logarithm of the total cases when \(t = \infty\).

It solves the analytical solution by using the invariance of two certain points when \(t = 0, \alpha = 0\), and when \(t = \infty, \alpha = a\). The diffusion slope adjusts the infection rate and the number of waves of the curve. The evolution of the logarithm of the total cases over time is expressed as Equation (4) when \(n = 1\). The time conversion constant \(b\) does not affect the results when considering relative time.

\[
\alpha(t) = \frac{ae^{bt}}{b+e^{bt}},
\]

\(t\) is the time in week; \(b\) is the time conversion constant.

2.2. Evaluation Method of Government Response Measures

The Likert scale is a kind of commonly used standard psychometric scale to measure responses (Li, 2013). A Likert scale can be divided into different levels to test the responses of participants. Each level matches its scale point. The measurements based on the Likert scale demonstrate good reliability (Bolger & Rowe, 2015). We put forward the five-point Likert scale methodology to create scores of government
response measures. Each scale point will be labeled according to its level of implementation: 1 = strongly lax (SL), 2 = lax (L), 3 = neither lax nor strict (NN), 4 = strict (S), and 5 = strongly strict (SS). The points in the Likert scale are not regarded as ordered numbers but are used to separate intervals. The score obtained represents the level of strictness of the government’s response to the epidemic.

We use the Dynamic Delphi method to get the scores of the Likert scale (Kim, Park, Kim, & Cho, 2016). A crucial difference between the Delphi and a traditional panel is structuring a group communication process rather than producing a consensus. Therefore, we believe that when the rounds end, that is when stability in the responses is attained, not when consensus is achieved (Linstone, & Turoff, 2011).

We drafted the training indicators before the formal scoring. The indicators of the training questionnaire are similar but not included in the Likert scale used in the formal scoring. We will give the experts feedback on the interval, average, and variance of each indicator scoring in the previous round from the second round so that they can revise their opinions. After scoring the training questionnaire by the experts selected in this article, we analyze the data by the average method. Furthermore, we set the minimum number of rounds for the training to be as stable as the rounds in the formal scoring.

$$E(C_j) = \frac{1}{m} \sum_{i=1}^{m} \frac{C_{ij}}{C_{ir}}$$  \hspace{1cm} (5)

$$Var(C_j) = \frac{1}{m} \sum_{i=1}^{m} \frac{C_{ij} - E(C_j)}{C_{ir}}$$  \hspace{1cm} (6)

$E(C_j)$ is the average value of indicator $j$; $Var(C_j)$ is the variance of indicator $j$; $m$ is the Total number of experts participating in the scoring of indicator $j$; $C_{ij}$ is the score of indicator $j$ by expert $i$; $C_{ir}$ is the authority coefficient of expert $i$.

The length of time an expert has worked in public safety determines the authority coefficient. $E(C_j)$ obtained in the last round in the Delphi method is the score of the indicator $j$ on the Likert scale. The flow chart is shown in Fig. 1.

### 2.3 Method of Correlation Coefficient

There are three commonly used correlation coefficients: Pearson correlation coefficient, Kendall correlation coefficient, and Spearman correlation coefficient (Taylor, 1990). The Pearson correlation coefficient is used to measure whether two data sets are on a line. The Kendall correlation coefficient is used to reflect the index of the correlation of categorical variables, and it is suitable for the situation where both categorical variables are classified in order. Spearman uses the rank-size of two variables for linear correlation analysis. Whether the Likert scale data conform to the normal distribution is controversial, the Pearson correlation is robust concerning skewness and nonnormality (Norman, G., 2010). We
chose the Pearson correlation coefficient in this article (Schober, Boer, & Schwarte, 2018).

The value of the Pearson correlation coefficient is $-1 \leq \gamma \leq 1$, and its positive or negative represents the positive and negative correlation of variables. Generally, we divide $\gamma$ into three levels, $|\gamma| < 0.4$ is a low-degree linear correlation; $0.4 \leq |\gamma| < 0.7$ is a significant correlation; $0.7 \leq |\gamma| < 1$ is high linear correlation. The Pearson coefficient will be affected by the sample size of the variable. The equation can be proposed as (7).

$$\gamma (X, Y) = \frac{\text{cov} (X, Y)}{\sqrt{\text{Var}[X] \text{Var}[Y]}}.$$  

(7)

3. ANALYSIS

3.1. COVID-19 Trends in Countries

We obtain the data from a widely cited website in the United States https://coronavirus.1point3acres.com/, whose data are integrated from the US CDC data set, Johns Hopkins University COVID-19 data set, local government reports, and many other sources. We use new confirmed cases with a seven-day average and total confirmed cases with a seven-day average as the vertical axis and horizontal axis, respectively. Data are collected until February 20, 2021. The trends of COVID-19 spread in the 13 selected countries are drawn and shown in Fig. 2. Confirmed cases more than 100 person as day 1.

As shown in Fig. 2, due to the change in the growth rate of new confirmed cases over time, the epidemic curves of these countries have more than one peak and trough. We divide the curve between two troughs of the new confirmed cases into one segment when the difference between them existed within a fixed range instead of all troughs. The epidemic trend curves are divided into one to four segments and are fitted by the e-RG equation to describe the characteristics of all segments. The obtained $\beta$ of trend curves for different countries represent the diffusion slope of COVID-19.

The evolution law of disaster dynamics believes that the spread rate of COVID-19 is very fast, and government measures could not be fully implemented at the early stage. The curves at this stage are mainly due to the dynamics of the epidemic spread. As the measures start to be implemented, the rate of
the spread is gradually brought under control. Control measures will affect the spread of the epidemic and cause it to decline at different rates at a later stage. Therefore, the spread rate of the epidemic and the peak of the total confirmed cases in various countries are different.

According to the assumptions of the e-RG model, we use the ln value of the total confirmed cases and the time in a week as the vertical axis and horizontal axis, respectively. The fitting of the diffusion slope and the peak value in the latter segment is based on the accumulation of the previous segment.

The results of curve segmentation fitting are shown in Figs. 3–5.

The fitting results are shown in Table I. We accumulate the peak values of each segment of a country up to February 20, 2021, and find that the fitted peak value of the last segment is close to the total number of confirmed cases obtained by actual statistics. Taking the index as the unit, the maximum error of the results is 6.17%.

In the following section, we give a total score of government response measures up to now.
3.2. Evaluation of Government Responses Measures

We summarize four levels of government response measures when faced with an epidemic by combining COVID-19 (Baker, Yang, Vecchi, Metcalf, & Grenfell, 2020; Eubank et al., 2020; Harapan et al., 2020; Wang, Wang, Chen, & Qin, 2020) and historical events (Daniel, 2020; Towers et al., 2016) in Table II.

We obtain the score table index by referring to the four levels of government response measures to the epidemic organized above (Chu et al., 2020; Hale, Petherick, Phillips, & Webster, 2020) and ISO 22325 (Security and resilience—Emergency management—Guidelines for capability assessment). There are several methods to create a composite index, including a simple additive or multiplicative index (Nicola et al., 2020). A simple additive with unweight index is employed because it is the easiest to explain and is not affected by the subjective view of the evaluator in the case of insufficient data. The table consists of seven categories with 51 indicators to assess the government response measures from the 13 selected countries. These 51 indicators are divided into 41 government response measure indices, and 10 social response measure indices beginning with an uppercase letter and lowercase letter in Table III, respectively.
Sixteen experts and researchers in our team are chosen to give an anonymous score to this table, as shown in Fig. 6.

In the article, we draft 10 indicators for training before the test. The experts consider three aspects when evaluating an indicator, including whether the government has promulgated these policies, the scope of implementation of the measures, and the degree of public cooperation. The 16 experts score the training questionnaire and revise their opinions based on the interval, average, and variance of the previous round’s scores. We conduct five rounds of scoring and observe that after the third round, the average of each indicator in each subsequent round was stable. Therefore, according to the training results, we set the number of test rounds as three rounds.

After three rounds of scoring in the formal scoring, the values of the indicators scores are calculated and summarized in Table IV. The scores of government response measures (G-Score) mainly indicate the strictness of government response measures. It ignores the economic impact, so it is not an assessment of the quality of the government response measures. The scores of social response measures (S-
Table II. Four Levels of Response Measures

| Level       | Id | Control measures                                                                 |
|-------------|----|-----------------------------------------------------------------------------------|
| Country     | 1  | Border control                                                                    |
|             | 2  | Rapid monitoring and patient finding                                              |
|             | 3  | Rapid case reporting                                                              |
|             | 4  | Rapid quarantine of suspected and confirmed cases                                 |
|             | 5  | Rapid detection of the Nucleic Acid of coronavirus                                |
|             | 6  | Fast and early treatment of confirmed cases                                       |
|             | 7  | Guarantee the supply of medicine and protective appliances                         |
|             | 8  | Effective contact tracing                                                          |
|             | 9  | Risk analysis and risk communication                                              |
|             | 10 | High priority of vaccines development                                             |
|             | 11 | Collaboration with countries and international organization                        |
|             | 12 | Support local government/community/organization                                    |
| City        | 1  | Lockdown                                                                          |
|             | 2  | Closing of cinemas and theaters                                                   |
|             | 3  | Cancellation of bars/party/other mass gatherings                                  |
|             | 4  | Closure of school/work                                                             |
|             | 5  | Travel bans                                                                       |
|             | 6  | Implementing personnel control measures in public                                |
|             | 7  | Hospital capacity/ control measures                                                |
|             | 8  | Opening of fever clinic                                                           |
|             | 9  | Ensure the supply of daily necessities                                            |
|             | 10 | Guarantee of the social security                                                  |
| Community   | 1  | Curb population flows                                                             |
|             | 2  | Access control                                                                    |
|             | 3  | Body temperature monitoring                                                       |
|             | 4  | Usage of health code                                                              |
|             | 5  | Reduction of unnecessary contact                                                  |
|             | 6  | Isolation suspected cases                                                         |
|             | 7  | Regular disinfection                                                              |
|             | 8  | Reinforce propaganda and education                                                |
|             | 9  | Guarantee of community service                                                    |
| Individuals | 1  | Social distancing measure                                                         |
|             | 2  | Self-isolation                                                                    |
|             | 3  | Wearing personnel protection equipment                                            |
|             | 4  | Performing hand hygiene frequently                                               |
|             | 5  | Avoiding touching eyes/nose/mouth                                                 |
|             | 6  | Ensure room ventilation                                                           |
|             | 7  | Maintaining environmental hygiene                                                |
|             | 8  | Personalized infectious disease risk prediction system                             |

Score) mainly indicate the degree of public cooperation with the government. The total scores (T-Score) of the two represent the synthesized strictness on the proposal and implementation of the government response measures to the epidemic.

We accumulate their daily scoring into a total score and converted scores into a five-point system based on the highest score. The scores of similar indicators in the two tables are similar. Since their 16 indices are related to government policies, we convert our G-Scores into a full 80-point system named NG-score for comparison. The comparison results show that their scores are similar to our scores for most countries, a total of 10, which also proved the reliability and repeatability of our results. In the 10 countries, six countries have similar scores to their scores and our G-Scores, including China, India, Brazil, Chile, the United States, and Japan. And for the
### Table III. Indicators of Government Response Assessment

| ID | Index | SL | L | NN | S | SS |
|----|-------|----|---|----|---|----|
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |
|    |        |    |   |    |   |    |

#### Macro measures of government

- **M1**: Value/support of government
- **M2**: Expertise/science and capabilities country owned
- **M3**: Legislation/policy against the outbreak
- **M4**: International influence/Contact with countries
- **M5**: Citizens’ trust/happiness/cooperation
- **M6**: Emergency coordination capability
- **M7**: Available resource/financial reserves
- **M8**: Social resource/financial call
- **M9**: Healthcare facilities
- **M10**: Highest emergency response for public health

#### Hospital measures

- **H1**: Expansion of healthcare personnel
- **H2**: Subsidies/protection for healthcare workers
- **H3**: New/reconstructed hospital in time
- **H4**: Number of hospital available
- **H5**: Reasonable treatment of patients
- **H6**: Reasonable disposal of medical waste

#### Public measures

- **P1**: Requirements/recommendations to wear masks
- **P2**: Guarantee of masks (purchase restrictions etc.)
- **P3**: Social distancing measures and hygiene rules
- **P4**: Household transmission control
- **P5**: Technical support for testing capability and etc.
- **P6**: Closure public places/entertainment venues
- **P7**: Travel bans/Suggestions
- **P8**: Division of key management areas
- **P9**: Blockades in areas with severe epidemics
- **P10**: School closure
- **P11**: Workplace closing
- **P12**: Timely public information

#### Overseas measures

- **O1**: Overseas evacuation
- **O2**: Immigration management in outbreak countries
- **O3**: Isolation and treatment for overseas imports
- **O4**: International aid humanitarian
- **O5**: Inspection of food and others

#### Cases & Resident measures

- **C1**: Heating and hygiene in homes
- **C2**: Comprehensive virus detection
- **C3**: Tracing suspected patients/contacts
- **C4**: Free/subsidy for the treatment of residents
- **C5**: Appropriate community management
- **C6**: Self-isolation (after travel, etc.)

#### Recovery measures

- **R1**: Ensure data authenticity
- **R2**: Reasonably relax control level
- **R3**: Resumption of work and production
- **R4**: Successfully developed vaccine
- **R5**: Protect from job loss and etc.

#### New normal measures

- **N1**: Disinfection monitoring in public places
- **N2**: Prohibition of large gatherings
- **N3**: Wearing of face coverings
- **N4**: Increase building ventilation
- **N5**: Case management
- **N6**: Logistic support
- **N7**: International travel restriction

#### Others

- **OT1**: Etc.
**Table IV.** Scores of Government Response Assessment

| Country | CN | IN | BR | CL | DE | IT | ES | CA | GB | FR | JP | US | KP |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|
| T-Score |    |    |    |    |    |    |    |    |    |    |    |    |    |
| G-Score | 210| 163| 160| 157| 201| 188| 196| 191| 187| 190| 206| 195| 186|
| S-Score | 44 | 28 | 29 | 30 | 35 | 36 | 39 | 39 | 39 | 39 | 44 | 40 | 37 |

**Macro measures of government**

| M1 | 5 | 3 | 4 | 4 | 4 | 4 | 5 | 4 | 3 | 4 | 4 | 4 | 2 |
| M2 | 4 | 4 | 3 | 3 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 |
| M3 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| M4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 3 |
| M5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 4 |
| M6 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 |
| M7 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 3 |
| M8 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| M9 | 4 | 2 | 3 | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 5 | 4 |
| M10 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**Hospital measures**

| H1 | 5 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 4 | 3 | 4 |
| H2 | 4 | 2 | 3 | 3 | 4 | 2 | 1 | 3 | 3 | 4 | 4 | 3 | 3 |
| H3 | 4 | 4 | 3 | 2 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 3 |
| H4 | 4 | 3 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| H5 | 4 | 2 | 2 | 2 | 3 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 |
| H6 | 4 | 3 | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 |

**Public measures**

| P1 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 5 | 5 | 3 |
| P2 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 4 |
| P3 | 3 | 2 | 3 | 3 | 5 | 4 | 5 | 3 | 4 | 3 | 5 | 3 | 3 |
| P4 | 4 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 4 |
| P5 | 5 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 3 |
| P6 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 3 |
| P7 | 5 | 3 | 4 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| P8 | 4 | 5 | 3 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| P9 | 4 | 4 | 4 | 4 | 3 | 5 | 4 | 3 | 3 | 4 | 3 | 4 | 4 |
| P10 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 3 |
| P11 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 5 | 4 | 4 | 4 |
| P12 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

**Overseas measures**

| O1 | 5 | 3 | 2 | 3 | 4 | 4 | 3 | 3 | 3 | 5 | 5 | 4 | 3 |
| O2 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 4 |
| O3 | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 3 |
| O4 | 4 | 3 | 2 | 2 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 2 |
| O5 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

**Cases & Resident measures**

| C1 | 4 | 4 | 3 | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 4 |
| C2 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 |
| C3 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 3 |
| C4 | 4 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 3 |
| C5 | 4 | 2 | 3 | 2 | 4 | 3 | 3 | 4 | 4 | 4 | 5 | 4 | 4 |
| C6 | 5 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 5 | 4 |

**Recovery measures**

| R1 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 3 | 4 |
| R2 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 4 |
| R3 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| R4 | 4 | 3 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 5 | 4 | 4 |
| R5 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |

**New normal measures**

| N1 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 |
| N2 | 4 | 2 | 2 | 2 | 3 | 3 | 4 | 3 | 3 | 4 | 3 | 3 | 4 |
| N3 | 5 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 5 | 5 | 3 |
| N4 | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| N5 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 |
| N6 | 5 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 4 | 3 |
| N7 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 |

**Note.** CN (China), IN (India), BR (Brazil), CL (Chile), DE (Germany), IT (Italy), ES (Spain), CA (Canada), GB (The United Kingdom), FR (France), JP (Japan), US (The United States), KP (South Korea).
Table V. Indicators of Government Response Measures

| ID | Index                          | Index                          |
|----|-------------------------------|-------------------------------|
| 1  | Testing policy                 | 9                             | International travel         |
| 2  | Contact tracing                | 10                            | Public campaigns             |
| 3  | Containment and health index   | 11                            | Public events                |
| 4  | Stringency index               | 12                            | Public gathering rules       |
| 5  | Vaccination policy             | 13                            | Public transport             |
| 6  | Debt relief                    | 14                            | School closures              |
| 7  | Income support                 | 15                            | Stay at home                 |
| 8  | Internal movement              | 16                            | Workplace closures           |

Fig 6. Names and affiliations of experts

other four countries, their scores maintain around 20 points, which are less than ours, including Italy, Spain, Canada, and the United Kingdom, as shown in Table VI.

There are differences between the scores of three countries, including Germany, France, and Japan. We believe that the main reason is that our scoring mainly considers the comprehensive strictness of the policy through taking the proposal and implementation of measures into account. They consider whether the government proposed measures and their impact on the economy. For example, we believe that it is better to prohibit international travel during the epidemic, but it is recommended when considering the economic effect.

From the result, it can be seen that since the beginning of the epidemic, the measures taken by these countries have been different. The higher score corresponds to the greater strictness of the measures. Different strictness of the measures has a different impact on the epidemic situation, which will be analyzed in the next section.

3.3. Correlation between Epidemic Trends and Response Measures

The total number of confirmed cases naturally rises over time and reaches a peak without intervention. The stringency and timeliness of the measures adopted by different countries affect the peak level of the epidemic trends.

We analyze the Pearson correlation $\gamma$ between the scores of government response measures and diffusion slope. The $\gamma$ between the T-score and the $\beta$ is $-0.44$, which shows a significant correlation. The strictness of government response measures affects the $\beta$ of the country. The stricter the measures, the smaller the $\beta$ of the epidemic with significant correlation.

We find that the first peak of most countries in this article appeared in May 2020 or later. The measures of these countries we counted show many countries gradually relaxed their response measures around May 2020 in order to recover economies, as shown in Table VII. This provides proof for our research of correlation.

4. DISCUSSION

We select 13 countries to test their epidemic trend curves and government response measures. Overall, for the global epidemic trend characteristics, the results indicate South Korea has the highest diffusion slope $\beta$, followed by the United Kingdom. India has the lowest $\beta$, followed by Brazil. We find the peak values of the last segment of the curves simulated are close to actual statistics and, the error is less than 6.17%.
For the government response measures, our studies establish the scores of the measures for the 13 selected countries. We summarize a table referring to the Likert scale containing seven categories with 51 indicators to access the government response measures. And select the Delphi method to invite 16 experts to conduct three rounds for scoring. The stringency of government response measures is compared and analyzed. The score of China is the highest, followed by Japan. Chile has the lowest score, followed by Brazil. It suggests that countries adopt a different level of strictness measures in the spread of the epidemic.

The Pearson correlation coefficient between the strictness of the measures adopted by the country and the epidemic trend parameter is –0.44, showing a significant negative correlation. The epidemic trend characteristics, including peaks and the number of waves, are obviously related to the strictness of government response measures. Countries adopt different levels of strict measures for the sole purpose of quickly controlling the epidemic. We believe it mainly depends on the acceptable economic threshold and the acceptable threshold of the epidemic. In this article, we classify countries into two groups according to the epidemic trends and government response measures, especially the number of waves of the curve. The different performance of these characteristics is largely dependent on whether the government takes rapid control of the spread of the epidemic.
the epidemic as the sole purpose or considers the economic development simultaneously.

Some countries with few waves of the epidemic trend curves have adopted a “surgical operation” method, mainly considering the epidemic situation and responding early and strictly. They set the acceptable threshold of the epidemic to a small value and the acceptable threshold of economic to a big value. With strict measures in a relatively short time, it controls the spread of the epidemic and reduces the number of new confirmed cases at a relatively low level. The controlled measures will have a great impact on the economy. In the late stage of the epidemic, the degree of curve rebound depends on the control of overseas imports. We divide them into group A including China, India, Brazil, and Chile.

Other countries with many multiple waves of the epidemic trend curves due to more leaping peaks adopt the “nutrition needle” method, which means that governments respond according to the epidemic situation. These countries consider not only the degree of national cooperation but also the economic impact on their own country. All such measures need to be guided by science, with appropriate protection of the rights of those impacted. The impact on the national economy is less significant compared to group A. We divide them into group B, including Germany, Italy, Spain, Canada, the United Kingdom, France, the United States, Japan, and South Korea. Less restrictive means to protect public health are challenging and risky. It is important to regularly update the stringency of the response measures, add new necessary measures, and remove inappropriate ones as the epidemic evolves. There is a pressing need for vaccines to control the increasing cases. Curves of epidemic development trends and government response measures adjustment rules for countries are shown in Fig. 7.

Countries should provide a response to the epidemic on the basis of careful consideration of the epidemic and its economic impact.

There are limitations to the study. The insufficient data we collected affects our more accurate scoring of countries, such as we can score on a regional basis instead of the whole country when there is sufficient data. Our conclusions are completely dependent on underlying data, such as the detection rate of countries, and the accuracy of the data affects our conclusions. The study is ultimately rooted in statistical correlations, so it shows trends for which there can be exceptions in the case of a small data set.

5. CONCLUSION

The COVID-19 has brought massive panic to countries around the world. We explore the relationship between the epidemic trend and the measures of the country in 13 selected countries. The exploration included three significant sections and requested limited information about the confirmed cases of the pandemic and government response measures in countries.

This article conducts a fitting analysis of epidemic trend curve characteristics to obtain the diffusion slope $\beta$. It indicates South Korea has the highest $\beta$ and India has the lowest $\beta$. A table containing seven categories with 51 indicators for government response measures assessment helps obtain strict government response measures in the countries. Sixteen experts gave their scores after three rounds of scoring through the Delphi method. The expert judgments show China with the highest score and India has the lowest score. We use the Pearson correlation coefficient to analyze the above data. The results demonstrate a significant negative correlation of 0.44 between the scores of government response
measures and the β, which show the stricter the measures, the smaller the peak value and longer time to reach a peak value of infection curves for countries.

Moreover, we divided the countries into two groups according to their epidemic trends and scores of government response measures. Further research needs more detailed data to conduct for a better result. The exploration improves our understanding of the measures against COVID-19 and enhances our control capabilities in the future.

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