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# Can India develop herd immunity against COVID-19?

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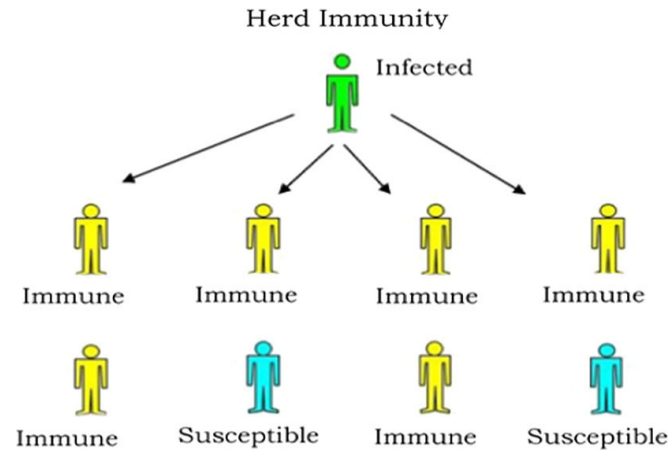
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**Abstract** World Health Organization declared the novel coronavirus disease 2019 (COVID-19) outbreak to be a public health crisis of international concern. Further, it provided advice to the global community that countries should place strong measures to detect disease early, isolate and treat cases, trace contacts and promote “social distancing” measures commensurate with the risk. This study analyses the COVID-19 infection data from the top 15 affected countries in which we observed heterogeneous growth patterns of the virus. Hence, this paper applies multifractal formalism on COVID-19 data with the notion that country-specific infection rates follow a power law growth behaviour. According to the estimated generalized fractal dimension curves, the effects of drastic containment measures on the pandemic in India indicate that a significant reduction of the infection rate as its population is concern. Also, comparison results with other countries demonstrate that India has less death rate or more immunity against COVID-19.

## 1 Introduction

The novel coronavirus disease 2019 (COVID-19) is an emerging epidemic responsible for infecting lots of people and killing lakhs globally since the first report till today, according to the World Health Organization (WHO). The WHO China Country Office has informed of cases of pneumonia unknown aetiology detected in Wuhan, Hubei Province of China, on 31 December 2019. A total of 44 case patients with pneumonia of unknown aetiology have reported to WHO by the national authorities in China since 31 December 2019 through 3 January 2020. Further, WHO received the information from the National Health Commission China that the outbreak is associated with exposures in one seafood market in Wuhan on 11 and 12 January 2020. The Chinese authorities identified a new type of coronavirus, which has been isolated on 7 January 2020. China shared the genetic sequence of the novel coronavirus for countries to use in developing specific diagnostic kits. During the period 13–20 January 2020, the Ministry of Public Health, Thailand, reported the first imported case of laboratory-confirmed novel COVID-19 from Wuhan, China, and the Ministry of Health, Labour and Welfare, Japan (MHLW), reported an imported case of laboratory-confirmed COVID-19 from Wuhan, China. Also, National IHR Focal Point (NFP) for Republic of Korea reported the first

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**Fig. 1** The principle of herd immunity

37 case of novel coronavirus in the Republic of Korea. According to WHO, globally 5,213,483  
 38 cases confirmed and 338,225 total deaths until 23 May 2020 in which the USA holding the  
 39 1st position in the world ranking in the number of confirmed cases of COVID-19 as in total  
 40 cases 1,555,537. Across the world, countries have implemented a lot of control procedures  
 41 to respond to COVID-19, with the aim of reducing communication and dropping mortality.  
 42 Particularly, some countries are in the process of measures public health and social processes  
 43 based on local epidemiology, while others are considering shrink these interventions. Besides,  
 44 countries have employed public health and social measures based on local risk assessments,  
 45 such as full lockdown, restricted local movement, and educational institutes are implementing  
 46 the virtual classes and industries are encouraging work from home, and regulated universal  
 47 travel measures.

48 Numerous papers have appeared modelling the forecasting the trends of epidemiology of  
 49 the disease [1–5], and many analyses have been done for the currently available epidemic data  
 50 [6–8]. The analysis made by using practical data shows that the power law kinetics with frac-  
 51 tal exponent provides a better fit to the current data for the number of deaths and spared rate  
 52 compared than the classical epidemiological approach that assumes an exponential growth  
 53 of the disease [9–12]. The idea of fractal dimension is useful in the categorization and quan-  
 54 tification of shape and texture which is used to describe systems with simple self-similarity  
 55 and regular fractals [13]. However, it is not enough to characterize sets having heterogeneous  
 56 scaling properties like growth of epidemic disease. For such a characterization Grassberger  
 57 has generalized the analysis with the notion of multifractals which implies a continuous  
 58 spectrum of exponents for the characterization of the system [14]. In this oversimplification,  
 59 an inhomogeneous fractal is considered to be associated with countably many subfractal sets  
 60 of dissimilar dimensions [13–18]. We analyse the COVID-19 infection data from the top 15  
 61 affected countries in which we observed the growth and death patterns of the COVID-19 are  
 62 heterogeneous. Hence, this paper applies the multifractal formalism on COVID-19 data with  
 63 the notion that country-specific transmission rates follow a power law growth nature.

64 Herd immunity is related to a scenario under which people develop immunity against  
 65 contagious infectious disease that materializes when the people is immune either through  
 66 vaccination or immunity developed through former infection and they become immune to  
 67 that disease. This provides indirect protection or herd immunity to those people who are not  
 68 immune to the disease, see for instance Fig. 1.

69 As on 25 May 2020, India is under the top 10 most infected countries with over 6000  
 70 per day recorded cases for four consecutive days. Data from Johns Hopkins University [6]  
 71 show that the total number of cases in India has surpassed that of Iran. After a sharp spikes

72 of cases since the second week of May, it can be predicted that the scenario will continue till  
 73 it can attain a maximum peak, may be in the month of June. After this intense period, herd  
 74 immunity can occur by a natural course of infection. In this report, using a brief comparative  
 75 analysis, we have shown that India can develop a significant mutation against the disease.  
 76 We have restricted our data analysis till 22nd May.

77 The work is organized as: In Sect. 2, necessary materials and method of multifractal formalism  
 78 are presented. In Sect. 3, the COVID-19 infection data from the top 15 affected countries are  
 79 described and discussed the heterogeneous nature of COVID-19 growth patterns. Further,  
 80 multifractal formalism is applied on COVID-19 data with the notion of power law growth  
 81 behaviour of virus. The generalized fractal dimension curves are estimated, and using these  
 82 results comparison is made between India with other countries. Conclusions of the work are  
 83 provided in Sect. 4.

## 84 2 Material and method of multifractality

85 This section presents the explanation of the material and method description applied in this  
 86 paper.

87 Prediction of the number of infected case for different diseases is the foremost task in the  
 88 healthcare system. In general, epidemiological analysis models assume that the number of  
 89 confirmed positive cases of COVID-19 grows exponentially with respect to fixed reproduction  
 90 rate  $n$ . Each person infected by the COVID-19 transmits to  $n$  number of new persons when  
 91  $n > 1$ , and then the total number of COVID-19 cases grows as

$$92 \quad n^{\frac{t}{\tau}} = e^{at} \quad (1)$$

93 here  $\tau$  is the incubation time which depends on the nature of COVID-19. The limitation  
 94 of exponential approaches is that it assumes each person transmits to  $n$  number of new  
 95 person without considering the inhibition due to the interaction with already infected people  
 96 such as lockdown, quarantine, restricted local movement, distance-learning, teleworking,  
 97 regulated travel, and other prophylactic measures. Therefore, in order to create short-term  
 98 predictions to prepare for the extent of the global pandemic infection data from the top 25  
 99 affected countries have investigated in [9]. Also, all country-specific infection rates follow  
 100 a power law growth behaviour and the scaling exponents per country are calculated in [9].  
 101 In this paper, the partition function of COVID 19 data for top 15 affected countries has been  
 102 estimated to apply analogy of multifractal formalism with COVID-19 transition, since the  
 103 partition function exhibits the power law distribution.

104 A set  $S$  of points describing an object can be divided into boxes labelled by an index  $i$   
 105 such that the  $i$ th box has  $N_i$  points of the total  $N$  points of the set. These points are sample  
 106 points describing the content of the underlying measure. Let us use the mass or probability  
 107  $\mu_i = N_i/N$  in the  $i$ th cell to construct weighted  $d$ -measure which we write

$$108 \quad M_d(q, \delta) = \sum_{i=1}^N \mu_i^q \delta^d = Z(q, \delta) \delta^d \quad (2)$$

109 The mass exponent  $\tau(q)$  for the set depends on the moment

$$110 \quad Z(q, \delta) = \sum_i \mu_i^q, \quad (3)$$

Author Proof

111 of order  $q$  chosen. Like  $N(\delta)$  of bare  $d$ -measure the partition function (if we may call)  $Z(q, \delta)$   
 112 also often exhibits power law distribution

113 
$$Z(q, \delta) \sim \delta^{-\tau(q)}, \tag{4}$$

114 where the exponent  $\tau(q)$  is called the mass exponent not the fractal dimension if it is nonlinear  
 115 in  $q$ . The mass exponent is more revealing than the simple fractal dimension as we shall soon  
 116 find it out. It can equivalently be defined as

117 
$$\tau(q) = - \lim_{\delta \rightarrow 0} \frac{\ln Z(q, \delta)}{\ln \delta}. \tag{5}$$

118 The generalized fractal dimension (GFD)  $D_q$  can be defined as

119 
$$D_q = \frac{1}{q-1} \tau(q) = \lim_{\delta \rightarrow 0} \frac{1}{q-1} \frac{\ln Z(q, \delta)}{\ln \delta}. \tag{6}$$

120 As  $q \rightarrow 1$ ,  $D_q$  converges to  $D_1$ , which is given by

121 
$$D_1 = \lim_{\delta \rightarrow 0} \frac{\sum_{i=1}^N \mu_i \ln \mu_i}{\ln \delta}, \tag{7}$$

122 where  $D_1$  is the **information dimension** and  $D_q$  is a monotonically decreasing function of  
 123  $q$  such that  $D_0 \geq D_1 \geq D_2$ . Here  $D_0$  and  $D_2$  denote the fractal dimension and correlation  
 124 dimension, respectively.

125 The set  $S$  is a country and it can be divided into boxes labelled by an index  $i$  such that  
 126 the  $i$ th box has  $N_i$  number of person affected by COVID-19 of the total number of persons  
 127 infected by every positive case  $N$  of the country  $S$ . Let us use the mass  $\mu_i = N_i/N$  in the  
 128  $i$ th cell to estimate the generalized fractal dimension by using Eq. (6).

129 **3 Results and discussion**

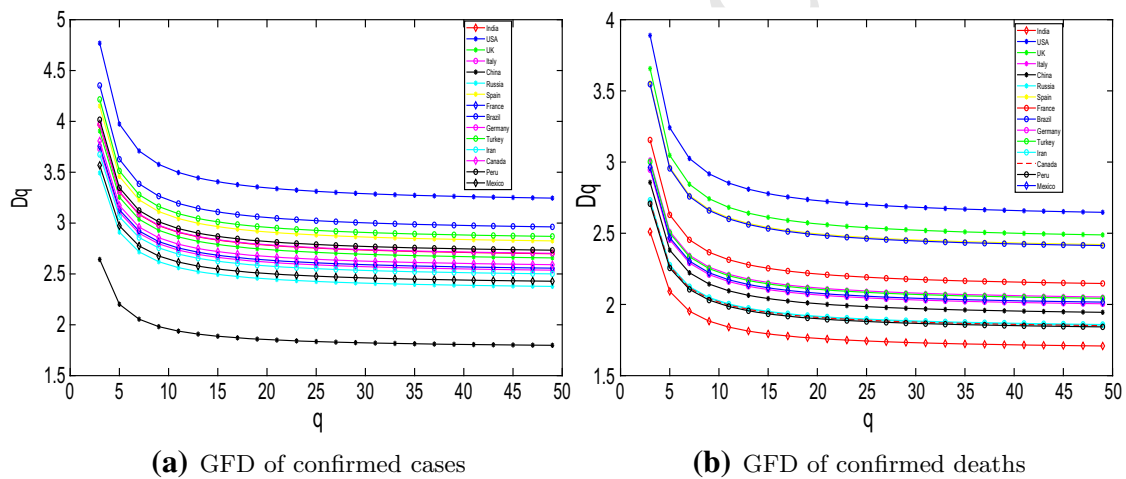
130 COVID-19 data have been downloaded from the publicly available JHU-CSSE (2020) data  
 131 repository provided by the Johns Hopkins University Center for Systems Science and Engi-  
 132 neering (JHUCSSE) [6] and Statistics and Research Coronavirus Pandemic (COVID-19)  
 133 available in the website of our world in data [7]. We have selected the data sets with the 15  
 134 most infections as presented in [6] on 22-05-2020 11:00 p.m. IST. The countries and their  
 135 infection counts and death counts are given in Table 1.

136 Figure 2a shows generalized fractal dimension result for the confirmed cases of 15 coun-  
 137 tries. For each country day zero is considered to be the day of the first confirmed case of  
 138 COVID-19. In each day the confirmed cases are normalized by dividing them by the total  
 139 number of case and obtained the partition function  $Z(q, \delta)$  by Eq. (3). Also, Fig. 2b reveals  
 140 generalized fractal dimensions of confirmed deaths corresponding to the confirmed case of  
 141 top 15 countries.

142 In Fig. 2a, a comparison of the 80 days of 15 different countries' case counts shows  
 143 that India has ranked 7th spread rate higher growth than UK, Canada, France, Germany, Iran.  
 144 Mexico, Russia and China, but lower growth than USA, Brazil, Turkey, Spain, Peru and Italy.  
 145 It is important to note, however, that due to the discrepancies of COVID-19 testing, these  
 146 countries reported numbers given by the World Health Organization are dependent on the  
 147 amount of conducted tests. Further, daily confirmed cases are subject to change depending  
 148 on a variety of factors.

**Table 1** Countries with the most COVID-19 infections as on 22.05.2020

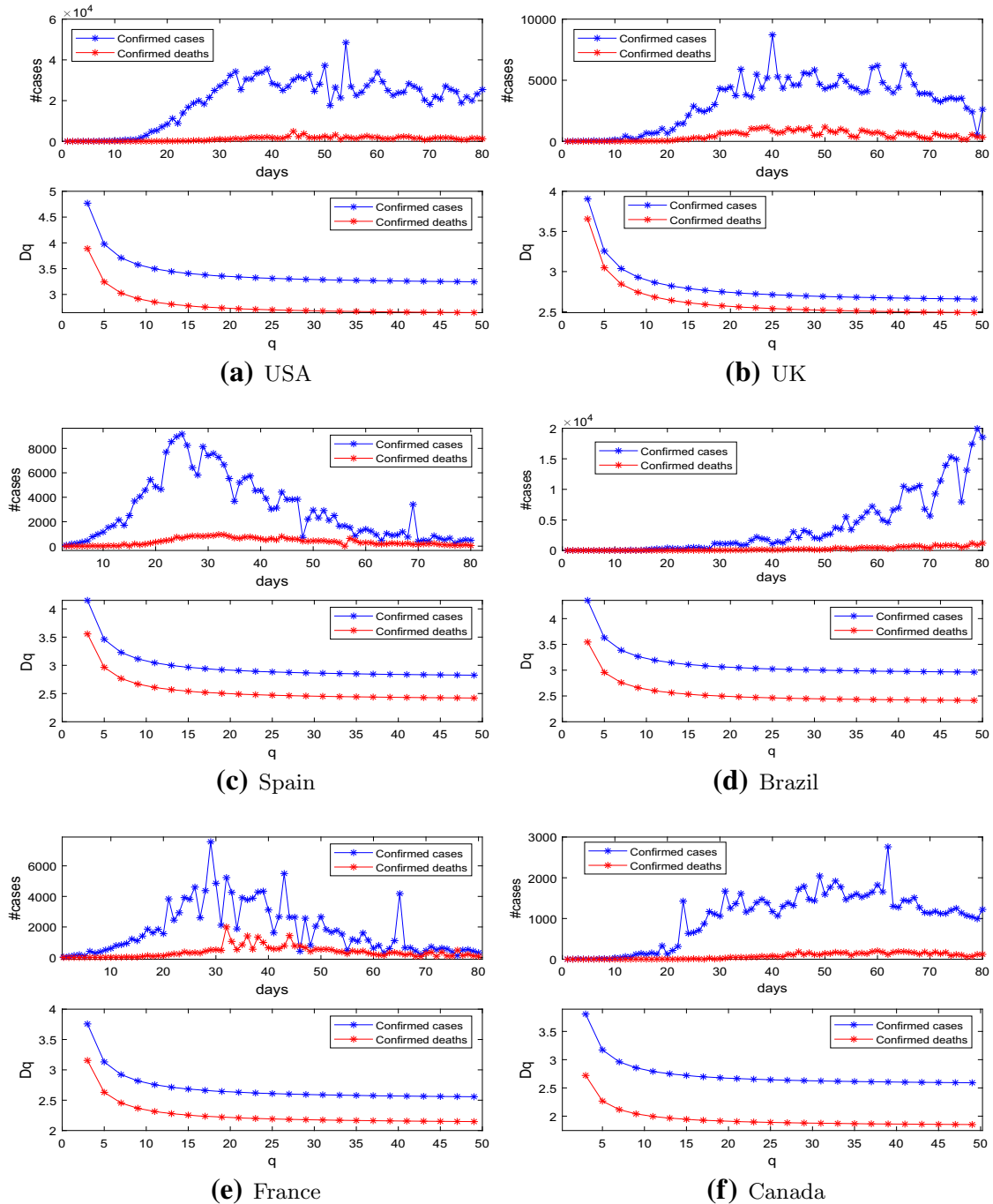
Country	No. of infections	No. of deaths
USA	1,555,537	96,001
Russia	317,554	3249
Brazil	291,579	21,048
UK	252,234	36,475
Spain	232,555	28,628
Italy	227,364	32,616
France	181,700	28,218
Germany	178,748	8352
Turkey	152,587	4276
Iran	129,341	7300
India	113,461	3726
Peru	104,020	3244
China	84,063	4638
Canada	81,575	6360
Mexico	56,594	6989



**Fig. 2** Generalized fractal dimensions of confirmed case and confirmed death of COVID-19

149 However, in Fig. 2b, a comparison of confirmed death counts between top 15 COVID-19-  
 150 infected countries from Fig. 2b elucidates that India has lower than all other 14 countries.  
 151 Preventing people from interacting, each infected person is probable to spread the COVID-19  
 152 virus to less people, slowing the speed of the virus spread and permitting healthcare systems  
 153 to handle the influx of patients. This shows the effectiveness of India’s continuous lockdowns  
 154 as follows: first 21 days full lockdowns 25 March 2020–14 April 2020, second lockdown 19  
 155 days from 15 April 2020–3 May 2020, third lockdown 14 days 4 May 2020–17 May 2020  
 156 and finally forth ongoing lockdown during 18–31 May 2020.

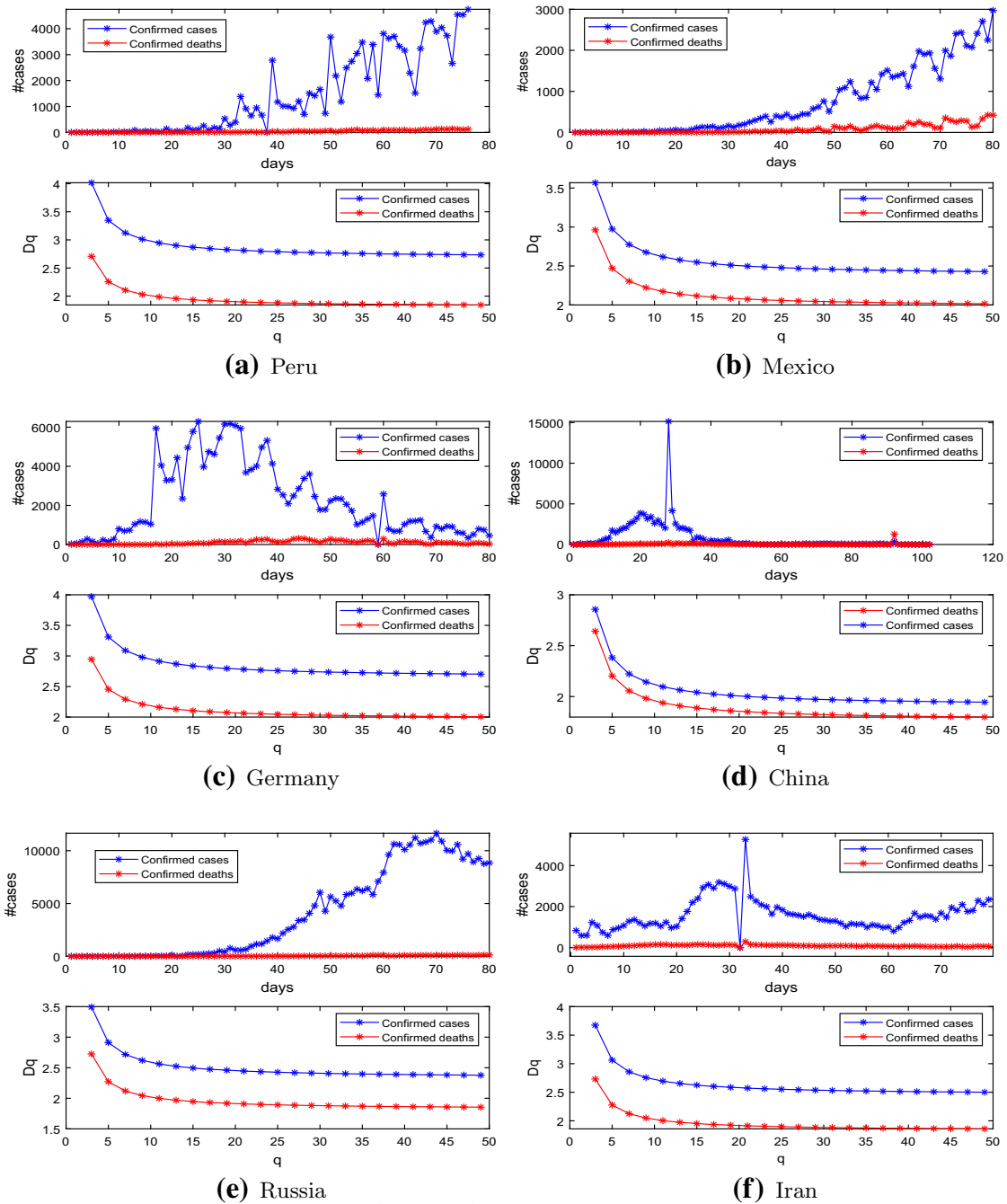
157 Figure 3 narrates the daily confirmed cases and confirmed deaths of USA, UK, Spain,  
 158 Brazil, France, Canada, and their corresponding generalized fractal dimensions begin with  
 159 3.89, 3.657, 3.557, 3.547, 3.155 and 2.72, respectively, which are shown in subplot. We  
 160 observed that the transmit rate of USA, UK, Spain, Brazil, Canada seems to follow the same  
 161 patterns, whereas France transmit rate is irregular not gradually increasing. Figure 4 describes



**Fig. 3** Daily confirmed case and confirmed death of COVID-19 and associated generalized fractal dimensions

162 the daily confirmed cases and confirmed deaths of Peru, Mexico, Germany, China, Russia,  
 163 Iran and associated generalized fractal dimensions curve starting with 2.707, 2.963, 2.946,  
 164 2.642, 2.725, 2.732, respectively, which are presented in subplot. Further, transmit patterns of  
 165 Peru, Mexico, Russia, Iran are similar and expect China remaining countries have mortality  
 166 rate 2.785 in average.

167 Figure 5 shows the daily confirmed cases and confirmed deaths of Italy, Turkey, India,  
 168 and their generalized fractal dimensions are revealed in subplot. Figure 5c clearly shows  
 169 that generalized fractal dimension of death rate of India is monotonically decreasing from

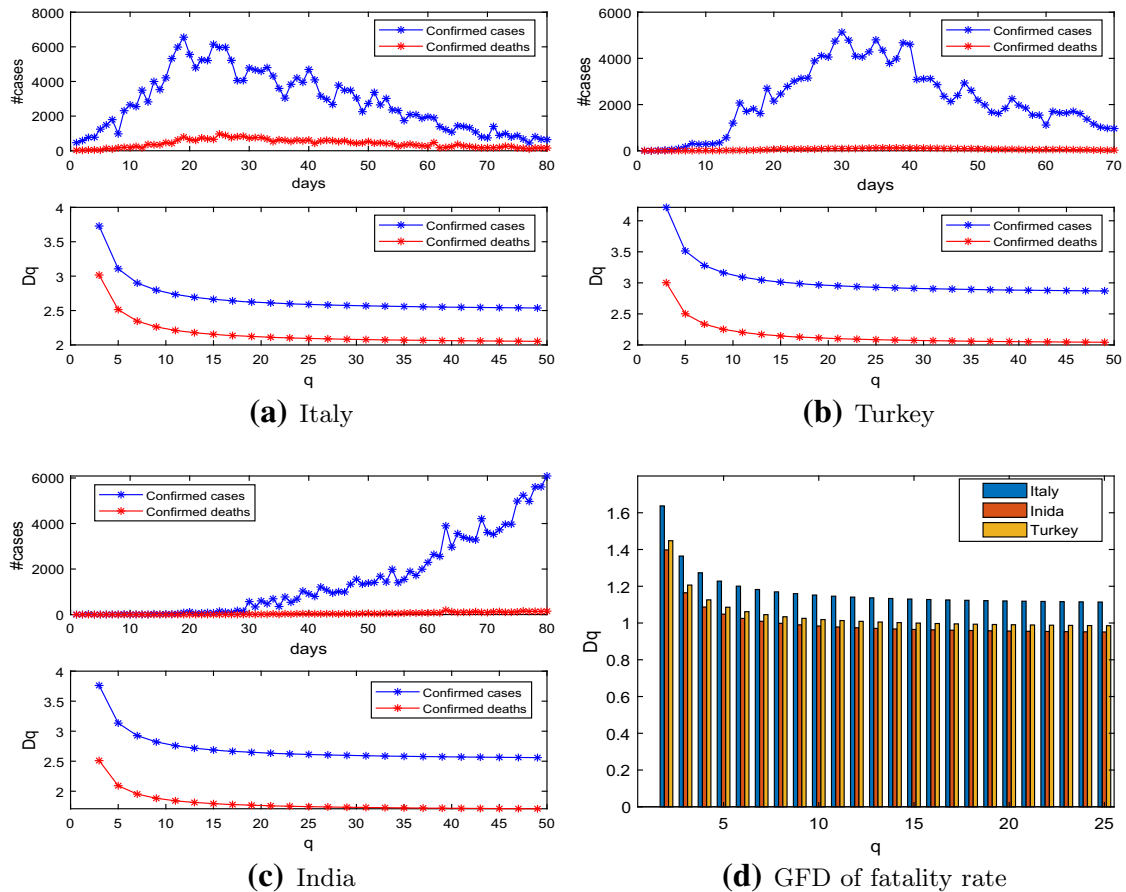


**Fig. 4** Daily confirmed case and confirmed death of COVID-19 and associated generalized fractal dimensions

2.51, whereas Italy and Turkey have initial value 3.016, 3.002, respectively. It should also be noted that remaining all 14 countries initial mortality rate starts above the value 2.51; hence, death rate of India is lesser than any other countries. This discrepancy might eventually get decreased or increased when more data on the outbreak in India will become available. However, the empirical data available as on 22.05.2020 are evident that India has more immunity against COVID-19. This is likely to be connected with many culture-related behaviours and to the presumed diversity in health conditions of the people.



Author Proof



**Fig. 5** Daily confirmed case and confirmed death of COVID-19 and associated generalized fractal dimensions

177 **4 Conclusion**

178 The analyses presented in this study demonstrated that India has less mortality rate of COVID-  
 179 19 as its total infected population is concern. Across the world, countries have executed a  
 180 number of control procedures to respond to COVID-19, with the aim of slowing down trans-  
 181 mission and dropping mortality. Particularly, India is in the process of scaling up public  
 182 health and social measures based on local epidemiology and on local risk assessments, such  
 183 as continuously four full lockdown, restricted local movement, and educational institutes  
 184 are implementing the distance-learning and businesses to teleworking, and regulated inter-  
 185 national and national travel measures. Finally, the death rate is likely to be connected with  
 186 many culture-related behaviours and to the presumed diversity in health conditions of the  
 187 people. Notice that mortality and transmit rate might eventually get decreased or increased  
 188 when more data on the outbreak of all countries will become available.

189 **References**

190 1. S. Zhao, Q. Lin, J. Ran, S.S. Musa, G. Yang, W. Wang, Y. Lou, D. Gao, L. Yang, D. He, M.H. Wang,  
 191 Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China,  
 192 from, to 2020: a data-driven analysis in the early phase of the outbreak. *Int. J. Infect. Dis.* **92**(2020),  
 193 214–217 (2019)

- 194 2. D. Fanelli, F. Piazza, Analysis and forecast of COVID-19 spreading in China, Italy and France. *Chaos Solitons Fract.* **134**, 109761 (2020)
- 195
- 196 3. K.O. Kwok, F. Lai, W.I. Wei, S.Y.S. Wong, J.W.T. Tang, Herd immunity-estimating the level required to
- 197 halt the COVID-19 epidemics in affected countries. *J. Infect.* **80**, e32–e33 (2020)
- 198 4. I. Ciufolini, A. Paolozzi, Mathematical prediction of the time evolution of the COVID-19 pandemic in
- 199 Italy by a Gauss error function and Monte Carlo simulations. *Eur. Phys. J. Plus* **135**, 355 (2020)
- 200 5. M.H. Dal Molin Ribeiro, R.G. da Silva, V.C. Mariani, L.D.S. Coelho, Short-term forecasting COVID-19
- 201 cumulative confirmed cases: perspectives for Brazil. *Chaos Solitons Fract.* **135**, 109853 (2020)
- 202 6. COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins
- 203 University. <https://github.com/CSSEGISandData/COVID-19>. Accessed on 23-05-2020
- 204 7. M. Roser, H. Ritchie, E. Ortiz-Ospina, J. Hasell (2020) Coronavirus pandemic (COVID-19). Published
- 205 online at OurWorldInData.org. Retrieved from <https://ourworldindata.org/coronavirus>
- 206 8. WHO, Coronavirus disease (COVID-2019) situation reports. <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation>
- 207
- 208 9. H.M. Singer, Short-term predictions of country-specific Covid-19 infection rates based on power law
- 209 scaling exponents. [arXiv:2003.11997v1](https://arxiv.org/abs/2003.11997v1)
- 210 10. A.L. Ziff, R.M. Ziff, Fractal kinetics of COVID-19 pandemic, medRxiv. <https://doi.org/10.1101/2020.02.16.20023820> (2020)
- 211
- 212 11. A.M. Ganan-Calvo, J.A. Hernandez Ramos, The fractal time growth of COVID-19 pandemic: an accurate
- 213 self-similar model, and urgent conclusions. [arXiv:2003.14284](https://arxiv.org/abs/2003.14284) (2020)
- 214 12. M. Li, J. Chen, Y. Deng, Scaling features in the spreading of COVID-19. [arXiv:2002.09199](https://arxiv.org/abs/2002.09199) (2020)
- 215 13. B.B. Mandelbrot, *The Fractal Geometry of Nature* (W.H. Freeman and company, New York, 1983)
- 216 14. P. Grassberger, Generalized dimensions of strange attractors. *Phys. Lett. A* **97**, 227–320 (1983)
- 217 15. H.G.E. Hentschel, I. Procaccia, The infinite number of generalized dimensions of fractals and strange
- 218 attractors, *Physica 8D*, 8(3), 435–444 (1983)
- 219 16. N. Sarkar, B.B. Chaudhuri, Multifractal and generalized dimensions of gray-tone digital images. *Sig.*
- 220 *Process.* **42**, 18–190 (1995)
- 221 17. S. Banerjee, M.K. Hassan, S. Mukherjee, *Fractal Patterns in Nonlinear Dynamics and Applications* (CRC
- 222 Press, London, 2019)
- 223 18. R. Uthayakumar, A. Gowrisankar, Mid-sagittal plane detection in magnetic resonance image based on
- 224 multifractal techniques. *IET Image Proc.* **10**(10), 751–762 (2016)