COVID-19 Data Published by Turkey is Fake or Not?

Abstract

Turkey attempt to control the fast-rising number of coronavirus cases and deaths since the spread of coronavirus disease 2019 (COVID-19) in every country. Likewise, researchers from different fields have been an effort to explore COVID-19 with distinctive aspects for minimizing the cost of a pandemic on the economy and social life. We know that is impossible reliable and unbiased results of studies without accurate data. Thus, if we gather inadequate data and analysis it, we will be faulty decisions and make policies. For this reason, Benford's Law may be useful for assessing the effects of the current control interventions and may be able to answer the question, ''How flat is flat enough?''. In this study, we explore whether the COVID-19 data published by Turkey is fake or not with Benford's Law.

Keywords: Benford's Law, COVID-19, data quality

1. Introduction

On December 31, 2019, twenty-seven cases of pneumonia with no known cause were discovered in Wuhan, Hubei Province, China. With over 11 million inhabitants, Wuhan is the most densely populated city in central China. The bulk of the affected positions were admitted to hospitals with fever, dyspnea, dry cough, and bilateral lung infiltrates as seen on imaging in the 27 cases. All the incidents were connected to the Huanan Seafood Wholesale Market in the area, which primarily sells a variety of fish as well as live animals like marmots, bats, chickens, and snakes (Lu et al., 2020). On January 7, 2020, the causative agent was discovered in throat swab samples taken by the Chinese Centre for Disease Control and Prevention (CCDC). The World Health Organization (WHO) announced the coronavirus disease 2019 (COVID-19) to be the cause of Serious Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (WHO Director-remarks General's at the media briefing on 2019-nCoV on 11 February 2020, 2020 February 11).

To date, most patients with SARS-CoV-2 have had developed mild symptoms, such as sore throat, dry cough, and fever. Many cases have been unexpectedly determined. However, a minority of patients have been known to develop fatal complications, such as septic shock, organ failure, severe pneumonia, pulmonary oedema, and acute respiratory distress syndrome. As per recent statistics, 54.3% of those diagnosed with SARS-CoV-2 were male with a median age of 56 years. Patients who required intensive care help were, on average, older and/or were previously diagnosed with comorbidities, such as cerebrovascular, cardiovascular, digestive, endocrine, and chronic respiratory disease. Those in intensive care were also more likely to report abdominal pain, dizziness, dyspnoea, and anorexia (Ruan et al., 2020).

Globally, 28 February 2021, there have been 113.472.187 confirmed cases of COVID-19, including 2.520.653 deaths, reported to WHO (https://covid19.who.int/ ,2021). As of February 28, 2021, there have been 2.701.588 total confirmed cases of COVID-19, including 28 569 deaths and, 3.317.516 diagnostic tests for COVID-19 (covid19.saglik.gov.tr/ ,2021).

Since COVID-19 became the most serious public health issue in many countries, the challenges of performing cross-country comparisons were raised. Comparing COVID19 statistics across countries presents several challenges. For example, developing reliable tests and criteria for diagnosing COVID19 in the early stages of the disease takes time; many countries have different diagnostic criteria; determining the cause of death of patients who show little of the known COVID-19 symptoms is difficult, and the leaders

of some countries do not provide much transparency in the flow of information on the disease. Data sharing practices at the early stages of the pandemic were inadequate and led to policy errors in Turkey as some country. Contrary to popular speculation, we use a statistical fraud detection technique, Benford's Law (1938), to assess the veracity of the statistics in Turkey. We believe these findings are significant because COVID-19 had a greater impact on Turkey, and some researchers may have gotten biased empirical results because of using inaccurate COVID-19 data. Furthermore, continuing doubts about the validity of the released statistics are worrying because they influence policy decisions made by countries that have seen epidemics later. Data sharing practices at the early stages of the pandemic were inadequate and led to policy errors in Turkey as some country. Contrary to popular speculation, we use a statistical fraud detection technique, Benford's Law (1938), to assess the veracity of the statistics in Turkey. These findings are important because Turkey was more affected from COVID-19 and some researchers by now get to biased empirical result due to use inaccurate COVID-19 data. In addition, the on-going doubts over the credibility of its published data are problematic as it impacts subsequent policy choices by countries that saw epidemics later.

2. Literature Review

Based on the distribution of the first digits of observed data, Benford's Law is used to detect fraud or flaws in data collection. In a forensic study looking for possible manipulations of the number of cases (Miranda-Zanettiet al., 2019), testing for the validity of Benford's Law in this dataset will be the best method, since a distribution of first digits that deviates from the predicted distribution could indicate fraud. For exponential processes with multiple magnitude changes, a Benford distribution of first digits emerges naturally (Stoltz &Michalski,2013). Benford's Law has been used to detect economic statistics manipulation by Nye and Moul (2007), Gonzales-Garcia and Pastor (2009), Rauch et al. (2011), and Holz (2014). Recent advances in statistics and economics have expanded Benford's Law beyond the natural environment to detect fraud in social activities such as accounting (Nigrini, 2015), international trade (Barabesi et al., 2018) and elections (Pericchi and Torres, 2011; Deckert et al., 2011). Based on the distribution of the first digits of observed data, Benford's Law is used to detect fraud or flaws in data collection. For exponential processes with multiple magnitude changes, a Benford distribution of first digits emerges naturally (Stoltz &Michalski,2013). Benford's Law has been used to detect economic statistics manipulation by Nye and Moul (2007), Gonzales-Garcia and Pastor (2009), Rauch et al. (2011), Holz (2014), and Nigrini (2015). Recent advances in statistics and econometrics have expanded Benford's Law beyond the natural environment to detect fraud in social activities such as accounting (Nigrini, 2012; Fernandes and Guedes, 2010), stock prices (Ley, 1996), international trade (Barabesi et al., 2018) and elections (Pericchi and Torres, 2011; Deckert et al., 2011). Alali and Romero (2013) used financial accounting data to see if there are any anomalies from Benford's Law on publicly accessible data in the United States for the decade beginning in 2001. The degree of manipulation was influenced by the effectiveness of legislation, increased scrutiny, and being audited by Big 4 firms. Grabinski and Paszek (2013) conducted a parallel analysis on European publicly traded firms, in which they analyzed the accuracy of selected accounting items such as net profit, equity, revenue, total assets, and profitability ratios created by these items with Benford's Rule. The accounting item distribution was found to be consistent with the theoretical distribution predicted by the statute. In the case of financial ratios, there was a deviation from the rule, but it was at an appropriate standard in the case of return on revenue and return on equity. Benford's Law has also been used to assess the accuracy of government-released macroeconomic results. As a result, Rauch et al. (2014) used data on the public deficit, public debt, and gross national product derived from the Eurostat database for 27 EU member states for the years 1999 to 2009. Greece, Romania, Latvia, and Belgium had the most data that

deviated from Benford's Law in terms of the first digit, according to the findings. However, it must be emphasized that deviation should not be interpreted as a clear indication of manipulation; rather, it implies that non-conformities should be investigated further. Nye and Moul (2007) conducted another analysis to see whether international macroeconomic figures complied with Benford's Law. Analyses were conducted on a dataset of 183 countries, with a subset of OECD countries being examined in greater depth. Overall, the findings showed that, while data from OECD countries complied with the law, developed country GDP figures had some inconsistencies.

3. Benford's Law

Benford's Law was an empirically discovered pattern in many real-life datasets for the frequency distribution of first digits (Joannes-Boyau et al., 2015). It notes that the leading digit is non-uniformly distributed in a consistent manner in many naturally occurring sets of numbers. Furthermore, the leading significant digit will most likely be tiny. For instance, 1 appears as the first digit 30.1 percent of the time, while 9 appears as the first digit 4.5 percent of the time. The number 1 appears more than six times more often than the number 9 in this case.

On a logarithmic scale, the probability of occurrence of digit d is proportional to the space between d and d +1, according to equation (1). In other words, on the logarithmic scale, the likelihood of two consecutive digits occurring is equal. The odds for the first digits are as follows;

$$P(d_1) = log_{10}(1 + \frac{1}{d_1}) \quad for \ all \ \ d_1 \in (1,2 \dots \dots,9) \qquad (1)$$

Furthermore, the first two digits probabilities can be denoted as;

$$P(d_1 d_2) = log_{10}(1 + \frac{1}{d_1 d_2}) \quad for \ all \ \ d_1 d_2 \in (11,12 \dots \dots,99) \quad (2)$$

where d_1 and d_2 denotes the first and the first two digits significant. From a statistical standpoint, a Borel probability measure P on R is Benford if P ($\{x \in R: S(x) \le u\}$) = log u for all u ∈ [1, 10), where S is the significant of a real number is its coefficient when it is expressed as a floating point. That is, the significant function S: R → [1, 10) is defined as follows: if x is a non-zero real number, then S (x) = u, where u is the unique number in [1, 10) with |x| = 10^ku for some k ∈ Z. Then, a random variable X is Benford if its distribution P_X on R is Benford, i.e., if P_X ($\{x \in R: S (x) \le u\}$) = log u for all u ∈ [1, 10).

The useful result for this study is that if U is a random variable uniformly distributed on [0, 1), then the random variable X = 10^U is Benford. To show this, let us say the cumulative distribution function of a Benford random variable X is F_X (x) = log_{10} (x) for all x ∈ [1, 10). Thus, a Benford variable X can be generated by 10^U, where U ∼ U(0, 1).

The Pearson's Chi-squared Goodness-of-Fit Test was used to assess the deviation between the observed and predicted first digit distribution from Benford's Law (Pearson ,1900). The statistic for the corresponding 2 can be calculated as;

$$\chi^2_{stat} = \sum_{i=0}^{9} \frac{(O_i - P_i)^2}{P_i}$$

where O_i is the observed frequency in each bin in the observed data, and P_i is the expected frequency based on Benford's distribution. In addition, we test a goodness-of-fit between observed frequency and expected

frequency with Kolmogorov-Smirnov D statistic (Kolmogorov, 1933), Chebyshev distance m statistic (Leemis, 2000), Euclidean distance d statistic (Cho and Gaines, 2007), Judge-Schechter mean deviation a^* statistic (Judge and Schechter, 2009), Shapiro-Francia type correlation test Joenssen's J_p^2 statistic (Shapiro and Francia, 1972), and Joint Digit Test T^2 statistic (Hotelling, 1931).

The test statistic works as a measure of the gap between the realization observed in the data and that implied by the Benford distribution; the larger the test statistic is, the stronger the deviation from the Benford distribution will be. Then, the null hypothesis (H₀) is that the observed distribution of the first significant digit in the case of interest is the same as expected based on Benford distribution; the alternative hypothesis (Ha) is that the observed distribution of the first significant digit in the case of interest is not the same as expected based on Bedford distribution. Particularly in analysis, if the null hypothesis can be rejected, the observed series does not satisfy Benford distribution and thus infers a possible manipulation of data or published data is fake.

3. Empirical Results

The Johns Hopkins University Corona Virus Research Center provides us with regular confirmed COVID-19 case data for Turkey. Our dataset contains 350 observations between the dates of March 16, 2020, and February 28, 2021. Since the COVID-19 pandemic is in its exponential growth phase, we use the growth rate of reported cases for Benford`s Law research.

Table 1. First digits distribution the growth of confirmed case and tests of significance.

digits	digits freq.	digits dist.	Benford freq.	Benford dist.	difference of freq.
1	109	31.143%	105.360	30.103%	3.640
2	52	14.857%	61.632	17.609%	-9.632
3	27	7.714%	43.729	12.494%	-16.729
4	36	10.286%	33.919	9.691%	2.081
5	29	8.286%	27.713	7.918%	1.287
6	23	6.571%	23.431	6.695%	-0.431
7	28	8.000%	20.297	5.799%	7.703
8	29	8.286%	17.903	5.115%	11.097
9	17	4.857%	16.015	4.576%	0.985

Chi-Squared test, χ^2 = 18.088 p-value = 0.021

Euclidean Distance Test, d=1.2823 p-value = 0.062

Hotelling T-square test , Hotelling T^2 = 8.2563 p-value = 0.041

Joenssen's JP-square test, $JP\text{-}square$ = 0.91379 p-value = 0.026

Kolmogorov-Smirnov (K-S) test, D = 1.215 p-value = 0.036

Chebyshev Distance (maximum norm) test, m= 0.89418 p-value = 0.074

Judge-Schechter Normed Deviation Test, a^* = 0.050319, p-value = 0.033

Figure 1. Comparison through bar charts of the distribution of COVID-19 confirmed case data in Turkey with first digits Distribution of Benford's Law.
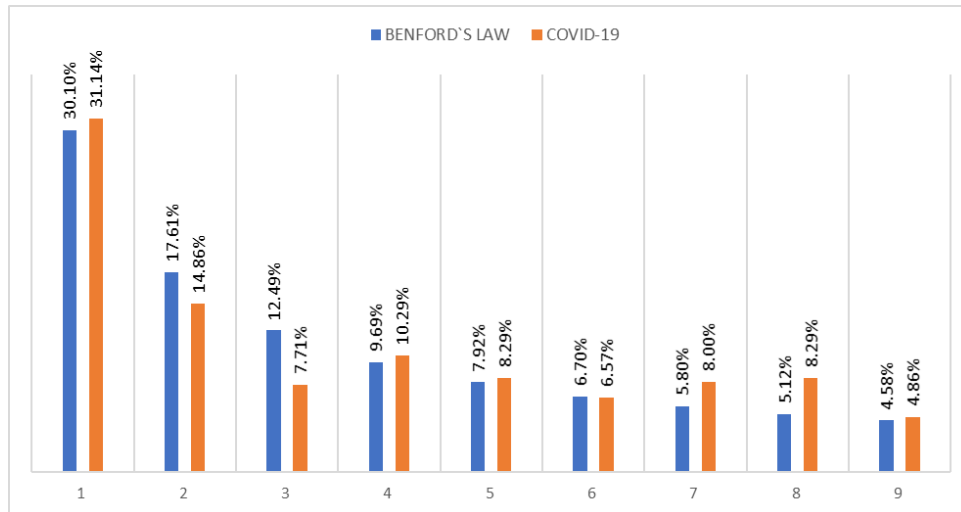
Table 1 and Figure 1 represent the growth of reported cases, first digit frequency and distribution, Benford's Law frequency and distribution, and the discrepancy between first digit frequency (observed frequency) and Benford frequency (expected frequency).Chi-Square test (p-value=0.021), Hotelling T-square test (p-value=0.041), Joenssen's JP-square test (p-value=0.026), Kolmogorov-Smirnov (K-S) test (p-value=0.036) and Judge-Schechter Normed Deviation test (p-value=0.033) do not reject the null hypothesis at the 1% level and support a Benford distribution. Furthermore, the Euclidean Distance test (p-value=0.062) and the Chebyshev Distance test (p-value=0.074) do not reject the null hypothesis at the 5% level, so the observed distribution of the first digit is the same as Bedford distribution at the sample period.

Most of the prior studies in the field of Benford's Law have focused on first or second digits. However, the joint analysis of the first two digits may also disclose anomalies that would be missed with the sole analysis of the first or second digits (Nigrini and Miller, 2007). In this respect, the observed frequencies of the first two digits are calculated against the expected frequencies of Benford's Law in Table 2.

Table 2. First two digits distribution the growth of confirmed case and tests of significance.

digits	digits freq.	digits dist.	Benford freq.	Benford dist.	difference of freq.
			Appendix A.		

Chi-Squared test, χ^2 = 95.493 p-value = 0.299
Euclidean Distance Test, d= 0.98899 p-value = 0.484
Hotelling T-square test , Hotelling T^2 = 25.377 p-value = 0.659
Joenssen's JP-square test, $JP\text{-}square$ = 0.6568 p-value = 0.337
Kolmogorov-Smirnov (K-S) test, D = 75.922 p-value = 0.163
Chebyshev Distance (maximum norm) test, m= 0.27686 p-value = 0.847

Table 2 and Appendix A produce the growth of confirmed cases frequency and distribution of the first two digits, the frequency and distribution of Benford's Law, the difference of the first two digit`s frequency (observed frequency) and Benford frequency (expected frequency). Chi-Square test (p-value=0.299), Euclidean Distance test (p-value=0.484), Hotelling T-square test (p-value=0.659), Joenssen's JP-square test (p-value=0.337), Kolmogorov-Smirnov (K-S) test (p-value=0.163) and Judge-Schechter Normed Deviation test (p-value=0.847), do not reject the null hypothesis at 1%, 5% and 10% levels and is that the

observed distribution of the second significant digit in the case of Turkey is the same as expected based on Benford distribution.

4. Results

In every disease outbreak around the world, underreporting occurs; however, keeping track of the COVID-19 outbreak in developing countries has been particularly difficult. Understanding the national and global burden of COVID-19, as well as managing COVID-19 prevention and control efforts, requires an accurate count of national COVID-19 cases. Epidemiologists can predict a disease's trajectory, researchers can develop treatments and vaccines, responders can track transmission, and the public can protect itself with accurate reporting. Without public trust, full transparency is impossible, and authoritarian regimes have a persistent public trust deficit. To ensure the successful control of the epidemic and the prevention of secondary problems, COVID-19 outbreak management requires strong, transparent, and accountable leadership and communication strategies at all levels.

Benford's Law calculates the approximate frequency of digits in any numerical data and is commonly used to verify the accuracy of published data. It is especially applicable to a wide variety of financial data, and auditors often use it to detect fraud, misuse, or distortion of accounting data. In this study, Benford's Law was used to regulate COVID-19 results. Benford's Law, on the other hand, does not recommend a foolproof method of detecting fraud or manipulation; rather, it identifies problem areas that may be manipulated data.

We focus on measure the compliance of COVID-19 confirmed case data reported by Turkey with Benford's Law. In light of increasing knowledge about applications of Benford's laws, we have analysed distributions' features of COVID-19 confirmed case over a long-time interval, that is, from March 2020, till the end of February 2021, amounting to 350 data points. We have addressed our considerations to the amount of the first, and first two significant digits. According to the different assessment approaches utilized for the first digits and first two digits, namely Chi-Squared test, Euclidean Distance test, Hotelling T-square test, Joenssen's JP-square test, Kolmogorov-Smirnov (K-S) test, Chebyshev Distance test and Judge-Schechter Normed Deviation test, reported the confirmed case of COVID-19 data between 16 Mart 2020 to 28 February 2021 seemed to be almost in perfect conformity with Benford's Law. According to all test results, the growth of confirmed case of COVID-19 seem to perfectly comply with Benford's Law's expected proportions, so we consider published data COVID-19 by Turkey is not fake.

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Appendix A.

digits	digits freq.	digits dist.	Benford freq.	Benford dist.	difference of freq.
10	10	2.857%	14.487	4.139%	-4.487
11	18	5.143%	13.226	3.779%	4.774
12	14	4.000%	12.167	3.476%	1.833
13	15	4.286%	11.265	3.218%	3.735
14	13	3.714%	10.487	2.996%	2.513
15	12	3.429%	9.810	2.803%	2.190
16	8	2.286%	9.215	2.633%	-1.215
17	11	3.143%	8.688	2.482%	2.312
18	5	1.429%	8.218	2.348%	-3.218
19	3	0.857%	7.797	2.228%	-4.797
20	4	1.143%	7.416	2.119%	-3.416
21	6	1.714%	7.071	2.020%	-1.071
22	6	1.714%	6.757	1.931%	-0.757
23	7	2.000%	6.469	1.848%	0.531
24	7	2.000%	6.205	1.773%	0.795
25	7	2.000%	5.962	1.703%	1.038
26	4	1.143%	5.737	1.639%	-1.737
27	3	0.857%	5.528	1.579%	-2.528
28	5	1.429%	5.334	1.524%	-0.334
29	3	0.857%	5.153	1.472%	-2.153

30	2	0.571%	4.984	1.424%	-2.984
31	1	0.286%	4.826	1.379%	-3.826
32	3	0.857%	4.677	1.336%	-1.677
33	4	1.143%	4.538	1.296%	-0.538
34	5	1.429%	4.406	1.259%	0.594
35	2	0.571%	4.282	1.223%	-2.282
36	0	0.000%	4.165	1.190%	-4.165
37	3	0.857%	4.054	1.158%	-1.054
38	3	0.857%	3.948	1.128%	-0.948
39	4	1.143%	3.848	1.100%	0.152
40	6	1.714%	3.753	1.072%	2.247
41	4	1.143%	3.663	1.047%	0.337
42	2	0.571%	3.577	1.022%	-1.577
43	2	0.571%	3.494	0.998%	-1.494
44	6	1.714%	3.416	0.976%	2.584
45	2	0.571%	3.341	0.955%	-1.341
46	4	1.143%	3.269	0.934%	0.731
47	1	0.286%	3.200	0.914%	-2.200
48	4	1.143%	3.134	0.895%	0.866
49	5	1.429%	3.071	0.877%	1.929
50	5	1.429%	3.010	0.860%	1.990
51	3	0.857%	2.952	0.843%	0.048
52	1	0.286%	2.895	0.827%	-1.895
53	2	0.571%	2.841	0.812%	-0.841
54	4	1.143%	2.789	0.797%	1.211
55	1	0.286%	2.739	0.783%	-1.739
56	3	0.857%	2.690	0.769%	0.310
57	4	1.143%	2.644	0.755%	1.356
58	3	0.857%	2.598	0.742%	0.402
59	3	0.857%	2.555	0.730%	0.445
60	3	0.857%	2.513	0.718%	0.487
61	2	0.571%	2.472	0.706%	-0.472
62	2	0.571%	2.432	0.695%	-0.432
63	1	0.286%	2.394	0.684%	-1.394
64	1	0.286%	2.357	0.673%	-1.357
65	6	1.714%	2.321	0.663%	3.679
66	1	0.286%	2.286	0.653%	-1.286
67	2	0.571%	2.252	0.643%	-0.252
68	0	0.000%	2.219	0.634%	-2.219
69	5	1.429%	2.187	0.625%	2.813
70	5	1.429%	2.156	0.616%	2.844
71	3	0.857%	2.126	0.607%	0.874
72	2	0.571%	2.097	0.599%	-0.097

73	2	0.571%	2.068	0.591%	-0.068
74	4	1.143%	2.040	0.583%	1.960
75	4	1.143%	2.013	0.575%	1.987
76	2	0.571%	1.987	0.568%	0.013
77	2	0.571%	1.961	0.560%	0.039
78	3	0.857%	1.936	0.553%	1.064
79	1	0.286%	1.912	0.546%	-0.912
80	1	0.286%	1.888	0.540%	-0.888
81	3	0.857%	1.865	0.533%	1.135
82	2	0.571%	1.842	0.526%	0.158
83	7	2.000%	1.820	0.520%	5.180
84	3	0.857%	1.799	0.514%	1.201
85	1	0.286%	1.778	0.508%	-0.778
86	4	1.143%	1.757	0.502%	2.243
87	3	0.857%	1.737	0.496%	1.263
88	2	0.571%	1.718	0.491%	0.282
89	3	0.857%	1.698	0.485%	1.302
90	1	0.286%	1.680	0.480%	-0.680
91	2	0.571%	1.661	0.475%	0.339
92	2	0.571%	1.643	0.470%	0.357
93	5	1.429%	1.626	0.464%	3.374
94	1	0.286%	1.609	0.460%	-0.609
95	1	0.286%	1.592	0.455%	-0.592
96	2	0.571%	1.575	0.450%	0.425
97	0	0.000%	1.559	0.445%	-1.559
98	2	0.571%	1.543	0.441%	0.457
99	1	0.286%	1.528	0.436%	-0.528