

Stock Price Validation *vis-à-vis* Benford's Law: The Adani Enterprises Limited Case

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Abstract: In the current world of technological advancements, data is generated each and every second. In fact, today's world is sustained on data, be it Google, or Meta, everyone needs data for their survival. Numerous instances are there, where data is morphed to cipher actual information. Recently, in 2023, controversies have been revolving around Adani Enterprises Limited. In this article, we would dive deep into the actual scenario by validating the "Adani" Stock Price Data. We made use of the well-known Benford's Law to do the same. To support the results, we have cross-validated the result using similar statistics. Validation was subjected to the Opening (Price when the Market Opened), Closing (Price at which the Market Closed), as well as Highest (Highest Price of the Day) Price of Stocks within the time frame of 8 years, between 2016 to 2023.

Keywords: Benford's Law; Stock Price; ChaosNet; Adani Enterprises Limited; Data Validation

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1. Introduction

Fraud [1] is a term that refers to practices, procedures, or systems that do not comply with the regulations that have been put in place for the benefit of the planet's young. Since the first scam occurred sometime around 300 B.C., hardly anything has changed. Days moved, civilization developed [2], colonization [3] took place, the economy [4] soared and crashed, but humanity's [5] greatest fundamental drive stayed the very same. Even though con artists are very cunning, nature's rules cannot be changed. The challenge, however, seems to be that tyrannies can do this, as Russia did in 2008, and upright unquantifiable, impressive bureaucratic [6] obstacles that reasonably believe and reach the conclusion that every unbiased and feasible supervision is an insurmountable problem of an interloper, or, as it happened in Ukraine in 2004, both parties of a dispute can paddock their own cadre of spectators affirming or disputing the validity of the other's findings.

Benford's law [7] also has the potential to provide us with reliable, collection points about the majority of frauds that occur in our daily lives, including vote rigging, GDP forgery, fraud with credit cards and revenue tax fraud.

The first digit law, sometimes referred to as the law of aberrant numerals or Benford's law, is a logarithmic [8] probability distribution model for the first digits of a randomized, extensive, and varied collection. The very first non-zero numeral on a number's far left, such as 8 for 81297, 9 for 99, and 0 for 0.007895, is considered to be the number's first significant digit. The suggested Benford's law states that in a delimited collection, the chances of a specific digit occurring as the initial figure reduces logarithmically as the

digit's value goes up from 1 to 9. In the table underneath, the predicted probabilities are shown.

Table 1. Numbers' likelihood of occurring according to Benford's law

Digit	Probability
1	0.301029
2	0.176091
3	0.124938
4	0.096910
5	0.079181
6	0.066946
7	0.057991
8	0.051152
9	0.045757

Benford's method was first applied in the investigative research and fraudulent detection fields by Mark J. Nigrini [9]. His assessment covered a wide range of cutting-edge theoretical studies on Benford's law as well as the complex judicial procedures that surround fraud judgments. In his book *Investigative Analytics*, by Wiley Publications, Mark J. Nigrini explains how to use tests like Benford's rule to find biases, errors, and fraud in financial and electoral data. The Wall Street Journal and the national media both praised him, and he published numerous studies on Benford's law.

According to Arno Berger and Theodore P. Hill's research report [10] on the randomness of Benford's law, this rule should only be applied to a limited number of unique datasets in order to produce accurate and convincing results; otherwise, it has more drawbacks than advantages.

The study paper by Hill, Theodore [11] attempted to describe the various applications of Benford's law in areas such as computer design, computational analysis, and the detection of fraudulent activity in financial information.

Jan H. P. Eloff's investigation [12] of Innocent Mbona focused on developing a solution to counteract malevolent social media bots. The study showed that, whereas an equivalent choice on a malevolent bot collection broke Benford's law, the characteristic choice nearly matched it on a typical sentient dataset. According to this study, Benford's law area's recognized alternatives are consistent and, consequently, the same as the data produced by PCA and the Randomized Forest technique on a comparable dataset.

The studies of Aleksandar Toi & Jernej Vii emphasize the application of Benford's law to cooperative scientific networks [13]. The report offered a special way to evaluate the advancement of the research organization. The report delves deeply into the discrepancies between many and varied research topics in Slovenia.

In the 2015–2016 fiscal year, the Adani group, an Indian multinational, generated around \$12 billion in sales. Ahmedabad, Gujarat, India is home to the company's headquarters. Adani is a prominent global infrastructure operator with a diversified portfolio of operations, including coal mining [14], coal trading, docks, electricity production [15], multi-modal logistics [16], renewable energy [17], and gas transmission [18] and distribution. The Adani has long been renowned for its capacity for expansion and national-building vision. Recently, there have been controversies around Adani Enterprises Limited. We have gathered data on the Adani Stock Price, subjected to Opening, Closing, and Highest price of the Day. In this article, we would dig deep into the scenario and would try to validate the data. Section 2 covers in detail the Adani Controversy. In Section 3, we will

be discussing Benford's Law and a few more related statistics. Section 4 aims towards
validating the Stock Price, and in Section 5, we would conclude the findings we have
reached, as an evaluation of the Stock Data.

2. "*Hum Adani ke hain kaun*" – The Indian Chaos

Rahul Gandhi, the commander of the Congress, claimed that "the real miracle" began
in 2014, following the BJP's victory in Delhi. He decided to make these combustible claims
against PM Narendra Modi on February 7 inside the Lok Sabha, alleging him of unfairly
endorsing business magnate Gautam Adani just at expense of the nation. Rahul held up
images of the PM meeting Adani aboard the latter's private aircraft to support the lengthy
list of claims. A Congress spokesman tweeted that "deMOcracy was cremated in the Lok
Sabha" when Speaker Om Birla subsequently deleted 18 comments Rahul uttered criticiz-
ing Modi & Adani after the blistering criticism of the PM was widely shared on social
media. The following day, in his response, Prime Minister [19] deftly redirected the dis-
cussion to criticism of himself, citing the "trust of 1.4 billion Indians" as a "protective shell
that no untruth could break." He responded to Rahul's criticism by referring to the Con-
gress as a party that was "drowning in arrogance and misery" and was determined to
perceive everything negatively. However, the 87-minute address by the Prime omitted
any reference of Adani, the figure at the epicenter of the controversy. The industrialist's
meteoric ascent, especially in the last ten years, has frequently sparked accusations of cro-
nyism from the opposing party, which notes that the industrialist's net wealth has in-
creased by even more than 200% since Modi became Prime Minister. A large portion of
this can be attributed to Modi's pro-business policy initiatives, initially as the chief minis-
ter of Gujarat and later as that of the prime minister, which led to Adani having won
various federal bids and infrastructure improvements in the country's harbors, airfields,
roadways, commuter trains, fossil fuel extraction, and renewable technology. Adani was
able to submit bids and secure contracts for six airports in 2018 thanks to a contentious
decision that was made by the Modi government, which ignored warning signs raised by
the department of budget and management and NITI Aayog and refused to make the
expertise a requirement. Adani seemed to have no prior expertise running runways, yet
the choice made his company overnight one of the largest private travel agencies in the
Nation. According to the records, the PPP branch of NITI Aayog was concerned that per-
haps the bidder lacked technical knowledge and would endanger the enterprise. Never-
theless, a strong number of administrators had previously resolved to remove the require-
ment for formal training. According to a bureaucrat who was present for the negotiations,
"there was a strong argument that it will expand the competition." Along with Adani,
other bidders included GMR Group, Zurich Airport, Cochin International Airport, and
Changi Airport. The Department of Economic Affairs (DEA) made reasons in favor of
capping the number of airports that corporate entities might own at two apiece, particu-
larly given that the airports up for bid required significant upfront investment. However,
a significant number of infrastructure improvement players had a negative net worth in
2018 while the conversations were taking place. Congress officials had already raised con-
cerns at the time, however, the Senior officials claim that choices were made with the as-
surances of ease of conducting business for the big players in consideration. Rahul claimed
that the entire India-Israel military partnership project had been given to Adani on a silver
platter, with all intergovernmental industrial agreements flowing to the firm, regarding
the Adani Group's entry into the military sector. Furthermore, this is taking place despite
the Adanis' complete lack of prior engagement with the industry. However, according to
military observers, the accusations are merely a "political slugfest." Regarding formal
training, they assert that no private Indian company could satisfy those competency
standards in a market that was previously monopolized by the governmental sector. They
can join forces with a foreign organization to gather experience as a group, preparing
themselves for the pre-qualification process. A defense lawyer states, "In this case, the
only dispute concerns whether any pre-qualification rules were loosened for the

Adanis or not." In addition to the missiles deal with the Indian government-owned aerospace and defense electronics manufacturer Bharat Electronics Limited (BEL), Adani and its partner Israeli companies also won the drone, radar, as well as communications agreements. An important MoD official mentions the Tata Group's foray into the aviation industry. "The Tata family have never even produced airplanes, but thanks to a partnership with Airbus, they are now producing C295 aircraft carriers in India. L&T has also been included in the nuclear submarine development. They also lacked significant experience "The official continues, "The only factor that counts is the company's monetary and technical capacity to fulfill the agreement.

The Hindenburg assessment has even been referred to as an onslaught on Delhi itself by Adani in response to the most recent events. However, despite demonstrations and sloganeering, both chambers of parliament repeatedly adjourned, failing to persuade the resistance. Mahua Moitra, a member of the Trinamool Congress, blasted the administration for supporting Adani in an impassioned speech in the Legislative Assembly, stating, "The pride of Country resides in the resilience of its organizational institutions, not in the wealth of one guy." She continued, "Don't let him tarnish your tenure in office with the stench of crony capitalism," gesturing to the finance seats. The reputation of our nation is at risk, so please urgently order a rigorous, comprehensive, and detailed investigation through all problems. A joint parliamentary inquiry into the Adani Group under the supervision of the Supreme Court is what the Congress plus 16 other opposition groups are demanding. Congress Prez Mallikarjun Kharge emphasized that only a JPC or an SC-monitored inquiry under the CJI could reveal the truth about the LIC and PSU banks 'forced' investments in businesses that have been alleged of financial crime and jeopardizing the difficult cash reserves of millions of Indians. A similar notice has been moved by a number of Lok Sabha members to discuss the matter in the lower chamber, while officials inside the Rajya Sabha likewise filed a notification pursuant to Rule 267. Assuring MPs "not to make unsupported claims," LS Speaker Birla rejected the proposals, and VP and head of the Rajya Sabha Jagdeep Dhankhar dismissed the resolutions as "not in order." The Minority, however, is determined. The opposition keeps up its onslaught on various fronts. The Congress has been questioning the government, "*Hum Adani ke hain kaun?* (Who are we to Adani?)" in a pun on a famous rom-com headline from the nineties. A sequel to this has been three questions posed to PM Modi every day on the subject since February 5 about this matter. Additionally, Congress members have been demonstrating in front of LIC and SBI offices and branches all over India. Both A-list public sector entities have a stake in the Adani business through stock holdings and loans, though both claim their commitments are far less than 1% of their building support. The UPA administration was ensnared in 2011 amid claims of fraud in the distribution of telecommunications licenses, coal licenses, and infrastructure improvements. The minority believes the Adani scandal may be a replay of that incident. In the lead-up to the 2019 elections, Rahul made allegations of bribery in the purchase of Rafale fighter aircraft, marking the last time the BJP was the focus of such an attack. At the time, that didn't gain much traction, and going after Modi directly was eventually thought to be ineffective.

3. Benford's Law

The revelation of Benford's law dates back to the 1800s, as Canadian-American astronomer Simon Newcomb [20] noticed that the earliest sheets in his log book, particularly those commencing with "1," were in much worse condition than the later ones. This discovery gave him a thought impulse, which eventually materialized as a theory. The likelihood of a single number being the first digit, according to a law put forward by Newcomb, is equal to $\log(\lambda + 1) - \log(\lambda)$.

A physicist named Frank Benford later saw this occurrence again in the early 1900s. He tested the formulations at the time on a large number of datasets and, to his

astonishment, found that almost all of them exhibited association with the concept. Nearly 20,000 samples were used in altogether by Benford for his study, that was a massive amount to handle at the moment. Benford was eventually given credit for this, though. In a nutshell, Benford's law asserts that a diversity of procedures or metrics that give rise to numbers such as investment returns, community of major cities, addresses of places, revenues of firms, and altitudes of turrets and houses define trends in the digits that could otherwise appear paradoxical where lesser data points are much more prevalent than bigger ones. Benford's law mathematical formulation is

$$\pi(\delta) = \log_{10}(\delta + 1) - \log_{10}(\delta) = \log_{10}\left(1 + \frac{1}{\delta}\right)$$

where,

$\pi(\delta)$ = Probability of Occurrence of the digit δ as the first digit $\exists \forall 1 \leq \delta \leq 9$

The graph for Benford's law (First digit) is

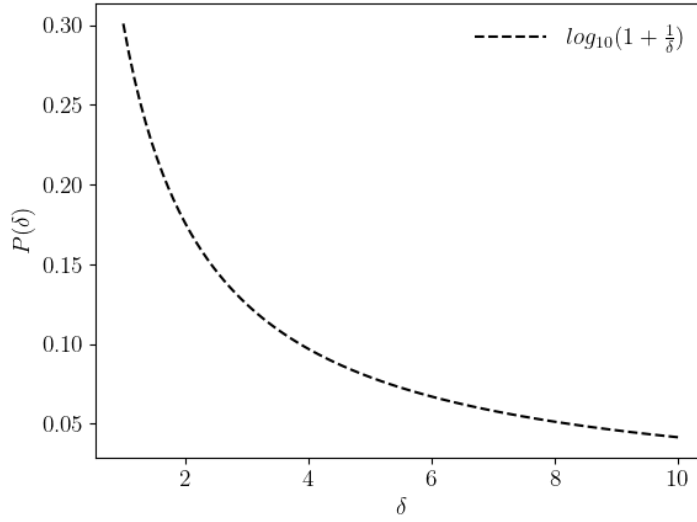


Figure 1. Benford's law graphic, with the initial numbers on the x-axis and their associated likelihood on the y-axis. $P(\delta)$ was constrained on the y-axes in the figure shown above, while δ was constrained on the x-axes.

The aforementioned formulation works only for the occurrence of digit δ as the 1st digit only, though another formulation has been generated that tells us about the probability of occurrence of digit δ as the ζ 'th digit. The phrase is written as follows:

$$\pi(\delta) = \sum_{\kappa=10^{\zeta-2}}^{10^{\zeta-1}-1} \log_{10}\left(1 + \frac{1}{10\kappa + \delta}\right)$$

$\pi(\delta)$ = Probability of Occurrence of the digit δ as the ζ 'th digit $\exists \forall 0 \leq \delta \leq 9 \forall \zeta > 1$

Generally speaking, Benford's law is as follows:

$$\pi(\delta) = \begin{cases} \log_{10}\left(1 + \frac{1}{\delta}\right) & \exists \forall 1 \leq \delta \leq 9 \text{ and } \zeta = 1 \\ \sum_{\kappa=10^{\zeta-2}}^{10^{\zeta-1}-1} \log_{10}\left(1 + \frac{1}{10\kappa + \delta}\right) & \exists \forall 0 \leq \delta \leq 9 \text{ and } \zeta > 1 \end{cases}$$

Hal Varian, an analyst, proposed using Benford's law to monitor for deception in the socio-economic statistics [21] in the late 1900s, and this was accomplished. Why not?

Benford's law rose to fame, and with good reason. After all, its range of operation was so broad. Benford's law has applications in many different fields, including the following:

1. By examining inconsistencies in the election [22] dataset, it is utilized to identify fraud.
2. It is used to research pricing digits.
3. It is utilized to validate genetic data [23].
4. It is used to check scientific works for errors [24].

4. A Scientific Mitigation

In this section, we would try to reach to a conclusion of the controversies following some well fledged scientific paradigms, especially, Benford's Law. We have collected the Adani Enterprise Stock Value between 2016 and 2023. Now, to apply Benford's Law in any dataset, we must perform some tests to confirm whether the collection is fit?. We have performed 3 tests on the collection, namely

1. *Mean Absolute Deviation Test*: Mean of the direct deviates from the origin. Suppose, we are having a dataset, $\{x_1, x_2, x_3, x_4, \dots, x_n\}$. It's Mean Absolute Deviation [25] is

$$\frac{1}{n} \sum_{i=1}^n \left| x_i - \frac{1}{n} \left(\sum_{i=1}^n x_i \right) \right|$$

For a collection to be suitable for implementing Benford's law, one must pass the Mean Absolute Deviation criterion within a certain band. Table 2. Shows the conformity range [26] from a Paper by Mark. J. Nigrini

Table 2. First-digit conformity range

Conformity Range	First Digits
Close Conformity	0.000 - 0.006
Acceptable Conformity	0.006 - 0.012
Marginal Conformity	0.012 - 0.015
Non-conformity	Above 0.015

2. *Mantissa Arc Test*: With the use of this experiment, we may identify the centroid for a certain group of mantissas which have been evenly dispersed around a unit circle. The pivot point, or the average vector, is the vector that results if the mantissa of integers is spread evenly over the unit circle (0, 0).
3. χ^2 Test: If there is a discrepancy in between conceptual stats and the actual data, it can be determined using Pearson's Chi-Squared test [27], a fitting experiment. Assuming that the null hypothesis is true as n approaches infinity, the χ^2 dispersion is as follows:

$$Z^2 = \sum_{i=1}^k \frac{(z_i - m_i)^2}{m_i} = \sum_{i=1}^k \left(\frac{z_i^2}{m_i} - n \right)$$

$m_i = np_i \forall i \in \mathbb{N}_n$ where p_i are the probabilities given by null hypothesis and $\sum_{i \in \mathbb{N}_n} p_i = 1$.

If the pixels on the scatter diagram are roughly identical to zero, the "Difference" graph, or scatter plot, that represents the distinction in between Artificial Likelihood and also the Likelihood by our suggested equation, substantially corresponds towards the authenticity of the collection. We may assess the dataset's fairness depending on this scatter graph by determining whether or not it detracts following our suggested formula. The most reliable procedure to determine whether the data fits Benford's law or does not is the Mean Absolute Deviation analysis. Chi-Square and Mantissa Arc tests are employed for additional conformance if the MAD test yields a score of "moderate conformity" but rather "non-conformity."

4.1 The Adani Stock Price Opening Value

The rate for which a commodity initially is dealt over an exchange there at start of a trading day is known as the Starting Price. Table 3 shows a few instances of the Stock Opening Price between the time frame 2016 – 2023.

Table 3. Stock Opening Price for Adani Enterprises Limited

Date	Stock Opening Price (USD)
01-01-2016	45.553741
04-01-2016	48.768658
05-01-2016	46.670792
06-01-2016	47.951309
07-01-2016	46.262115
08-01-2016	44.6819
11-01-2016	44.136997
12-01-2016	44.872616
13-01-2016	44.572922
14-01-2016	43.019951
...	...
16-01-2023	3720
17-01-2023	3620
18-01-2023	3648
19-01-2023	3470
20-01-2023	3450
23-01-2023	3443.050049
24-01-2023	3447.449951
25-01-2023	3422
27-01-2023	3335
30-01-2023	2850

The complete dataset is made available at <https://github.com/Anurag-Dutta/Adani/blob/main/open.csv>. Firstly, we have considered the first digit of the entries of Opening Stock Price Column. Table 4. shows the digit wise frequency of the same.

Table 4. Digit – wise frequency for 1st Digit place for the Stock Opening Price.

Digit	Frequency
1	712
2	213
3	269
4	180
5	64
6	80
7	108
8	92
9	32

Adding up all the entries of the Frequency Column, we get,

$$\sum_{i=1}^9 f_i = 1750$$

Then, using the equation

$$P(i) = \frac{f_i}{\sum_{i=1}^9 f_i} = \frac{f_i}{1750} \quad 287$$

we estimated the artificial likelihood or, more accurately, the realistic likelihood and contrasted it to the mathematical likelihood by Benford's Law. The theoretical probabilities have been demonstrated on the Table 1. Figure 2 contrasts the same. 288
289
290

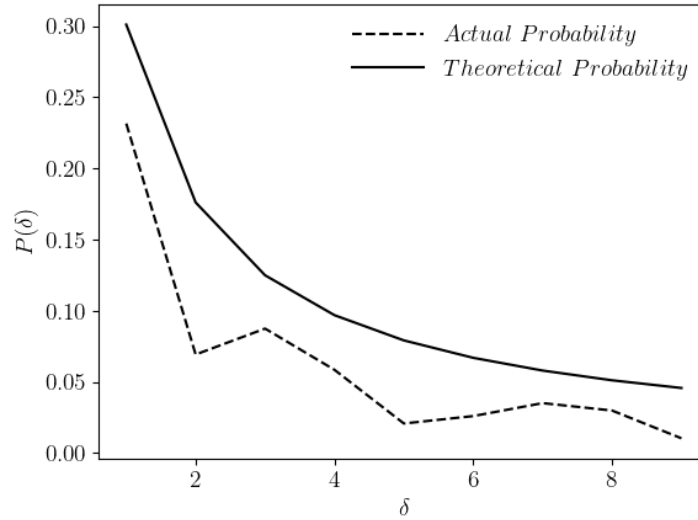


Figure 2. Contrast between Actual and Theoretical Probabilities taking into consideration, Opening Price of the Adani Stock Price. 291
292
293

The mean squared error, 294

$$\sum_{i=1}^9 (y_i - \hat{y}_i)^2 \quad 295$$

turns out to be 0.026420815, which is in acceptable ranges. 296

4.2 The Adani Stock Price Closing Value 297

The final transaction price of a securities well before exchange formally shuts for regular trading is known as the closing price or cash value. Table 5 shows a few instances of the Stock Closing Price between the time frame 2016 – 2023. 298
299
300
301

Table 5. Stock Opening Price for Adani Enterprises Limited 302
303

Date	Stock Opening Price (USD)
01-01-2016	44.872616
04-01-2016	45.907928
05-01-2016	45.880684
06-01-2016	46.480076
07-01-2016	42.502296
08-01-2016	43.946285
11-01-2016	42.992706
12-01-2016	43.319649
13-01-2016	42.066376
14-01-2016	42.148109
...	...
16-01-2023	3600
17-01-2023	3560.199951

18-01-2023	3527.100098
19-01-2023	3426.699951
20-01-2023	3440.949951
23-01-2023	3412.550049
24-01-2023	3430
25-01-2023	3315
27-01-2023	2712
30-01-2023	2665

The complete dataset is made available at <https://github.com/Anurag-Dutta/Adani/blob/main/close.csv>. Firstly, we have considered the first digit of the entries of Closing Stock Price Column. Table 6. shows the digit wise frequency of the same.

Table 6. Digit – wise frequency for 1st Digit place for the Stock Closing Price.

Digit	Frequency
1	718
2	207
3	301
4	152
5	66
6	83
7	113
8	94
9	17

Adding up all the entries of the Frequency Column, we get,

$$\sum_{i=1}^9 f_i = 1750$$

Then, using the equation

$$P(i) = \frac{f_i}{\sum_{i=1}^9 f_i} = \frac{f_i}{1750}$$

we estimated the artificial likelihood or, more accurately, the realistic likelihood and contrasted it to the mathematical likelihood by Benford's Law. The theoretical probabilities have been demonstrated on the Table 1. Figure 3 contrasts the same.

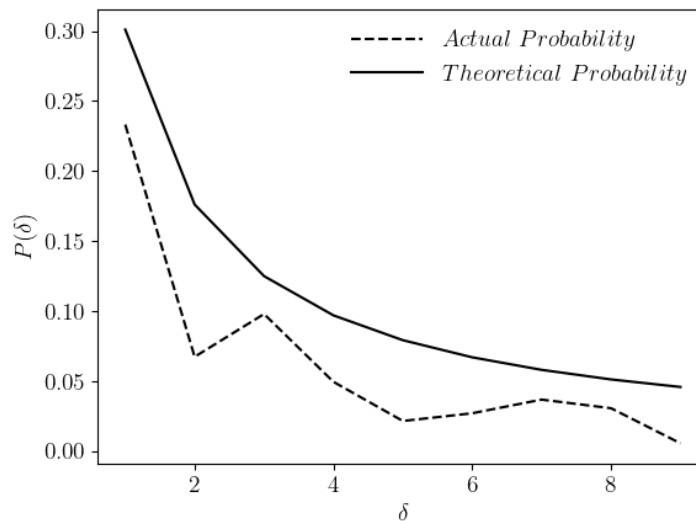


Figure 3. Contrast between Actual and Theoretical Probabilities taking into consideration, Closing Price of the Adani Stock Price.

The mean squared error,

$$\sum_{i=1}^9 (y_i - \hat{y}_i)^2$$

turns out to be 0.026861614, which is in acceptable ranges.

4.3 The Adani Stock Price Highest Value

Table 7 shows a few instances of the Stock Highest Price between the time frame 2016 – 2023.

Table 7. Stock Highest Price for Adani Enterprises Limited

Date	Stock Opening Price (USD)
01-01-2016	49.422543
04-01-2016	50.158157
05-01-2016	48.823151
06-01-2016	48.468964
07-01-2016	46.262115
08-01-2016	45.226803
11-01-2016	45.717213
12-01-2016	45.635475
13-01-2016	46.643543
14-01-2016	44.136997
...	...
16-01-2023	3739.949951
17-01-2023	3649.600098
18-01-2023	3648
19-01-2023	3537.699951
20-01-2023	3477.350098
23-01-2023	3460
24-01-2023	3508
25-01-2023	3428
27-01-2023	3346.5
30-01-2023	3037.550049

The complete dataset is made available at <https://github.com/Anurag-Dutta/Adani/blob/main/high.csv>. Firstly, we have considered the first digit of the entries of Highest Stock Price Column. Table 8. shows the digit wise frequency of the same.

Table 6. Digit – wise frequency for 1'st Digit place for the Stock Highest Price.

Digit	Frequency
1	708
2	211
3	244
4	207
5	67
6	76

7	94
8	94
9	49

Adding up all the entries of the Frequency Column, we get,

$$\sum_{i=1}^9 f_i = 1750$$

Then, using the equation

$$P(i) = \frac{f_i}{\sum_{i=1}^9 f_i} = \frac{f_i}{1750}$$

we estimated the artificial likelihood or, more accurately, the realistic likelihood and contrasted it to the mathematical likelihood by Benford's Law. The theoretical probabilities have been demonstrated on the Table 1. Figure 4 contrasts the same.

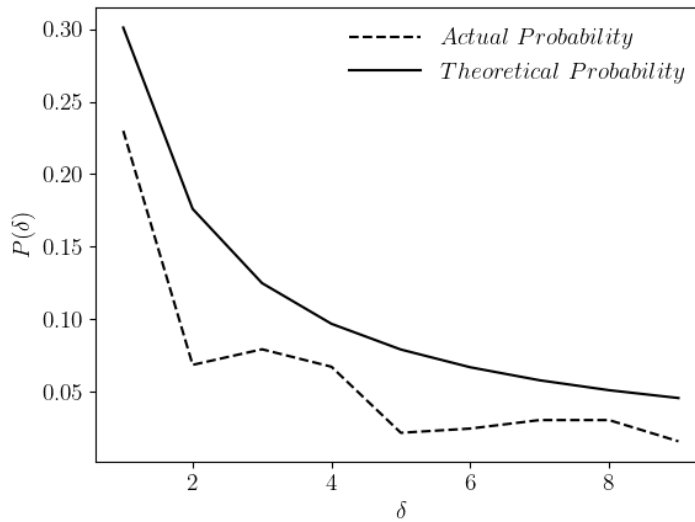


Figure 4. Contrast between Actual and Theoretical Probabilities taking into consideration, Highest Price of the Adani Stock Price.

The mean squared error,

$$\sum_{i=1}^9 (y_i - \hat{y}_i)^2$$

turns out to be 0.02672328, which is in acceptable ranges.

5. Conclusion

The Adani Stock Price clearly deviates Benford's Law within permissible ranges. For the Opening, Closing, as well as Highest Price, in the window of 2016 - 2023, the collection, followed the Law of Anomalous Numbers. Though, it wouldn't be justified to conclude, the Adani Controversy drawing attenuation from the Stock Price data, we can say that there haven't been any data morphing [28] on the Adani Stock Price Data, as per its accordance with the Benford's Law.

The authors encourage future works on the case to reach out a more concrete conclusion using any other measures that could be futuristic enough to rule out the jeopardize. Other Statistical laws like Zipf's Law, Weber's Law, etc could also be drawn into the frame as a scope of future works.

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