

# Benford's Law in the Analysis of Inventories of Portuguese Companies

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**Abstract:** The article aims to check whether the financial data disclosed by companies comply with natural laws in terms of the resources used. We recognise the compliance of the distributions with the Benford distribution as the compliance of financial data with natural law. The fit of empirical distributions of the analysed variables in Portuguese companies will be presented in charts and measured using Mean Absolute Deviation (MAD). In the article, we analyse the inventory values of Portuguese companies in the years 2016 - 2020. The study results indicate that for one sector (Real Estate), there is no consistency with the Benford distribution. The study's preliminary results suggest that inventory values follow the natural distribution of digits, which was described by a mathematical formula by Benford. The non-conformity in the Real Estate sector requires a deeper analysis of the results, which will be continued further research.

**Keywords:** Benford Law; assets; financial reporting; inventories

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## 1 Introduction

Economic activity is subject to many economic laws. One of these laws is the law of supply and demand. The demand and supply create the transaction price for the resources purchased and consumed by the companies. Entrepreneurs work by interacting with each other. Their decisions may affect other economic units. From this perspective, all entities worldwide can be compared to living organisms.

The last decade was a historic milestone in the evolution of accounting in Portugal. After several years of discussion, the Accounting Standardization System (SNC) came into application in the 2010 financial year, when this accounting standard was in force. All these accounting regulations in the Accounting Standardization System (SNC) are published in the Portuguese Republic Gazette, being the exact source of law. The implementation of the SNC is the result of the adoption by the European Union and respective endorsement by Portugal of the International Accounting Standards (IAS) and the International Financial Reporting Standards (IFRS) issued by the (IASB).

Because of the previous Official Accounting Plan (POC) started in 1977 (POC 77) and its update in 1989 (POC 89), the SNC represents an exponential evolution as it starts to present a conceptual structure. The main objectives are to help in the preparation of financial statements, in the application of NCRF, help in the adherence of the financial statements to the NCRF, assistance users in interpreting the information contained in the financial statements.

The article aims to check whether the financial data disclosed by companies comply with natural laws regarding the resources used. For this purpose, we use Benford's Law to measure this phenomenon in this article. Benford's law relates to the orderly occurrence of numbers in measuring natural phenomena. In their respective places in number, the digits have the distribution described by Benford. Benford's law is successfully used to analyse anomalies in the distributions of digits that may result from human disturbances in measured natural phenomena.

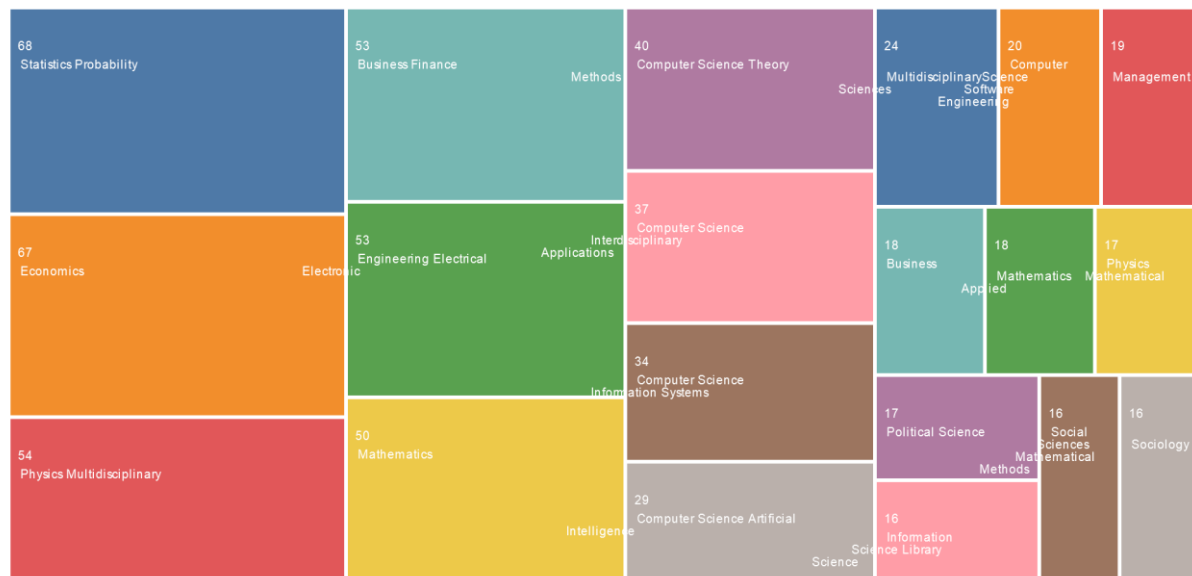
The article focuses on the analysis of assets, including current assets. Companies have adequate inventory levels in most activities, whether in the manufacturing or service sectors. Inventories may be materials used in production, goods or finished products. A characteristic feature of the resources mentioned above is a consistent valuation method based on historical transaction values. Regarding NCRF 18, which provides the accounting treatment of inventories, two options are also provided: Fair Value and Net realisable value. According to the standard mentioned above, fair value is the amount at which an asset that fits into the inventory concept can be transacted between two companies without any relationship between them. Net realisable value is based on an estimated selling price, less estimated finishing costs, and selling costs. In the balance sheet, inventories must be measured by the lower two measurement criteria.

The analysis of the use of Benford's Law in detecting anomalies in financial statements covers a period of five years for which data is available in the Thomson Reuters Eikon database (2020-2016). The survey results show whether there are anomalies in the values of selected groups of assets and whether the anomalies are general or concern a chosen sector of economic activity.

The proposed research is a preliminary study. Therefore we limit ourselves to selected balance sheet items from the financial statements of Portuguese companies. The authors plan to extend the analysis to include other assets, liabilities, revenues, and costs.

## 2 Literature Review

Benford's law is a widely used tool to assess the occurrence of anomalies in empirical distributions. Based on a review of manuscripts from the last ten years, after the phrase "Benford" and "Law" from the Web of Science (WoS), it can be concluded that the use of Benford's Law takes place in many scientific disciplines (Figure 1). This law was often used in social sciences: Economics, Business Finance, and Management.

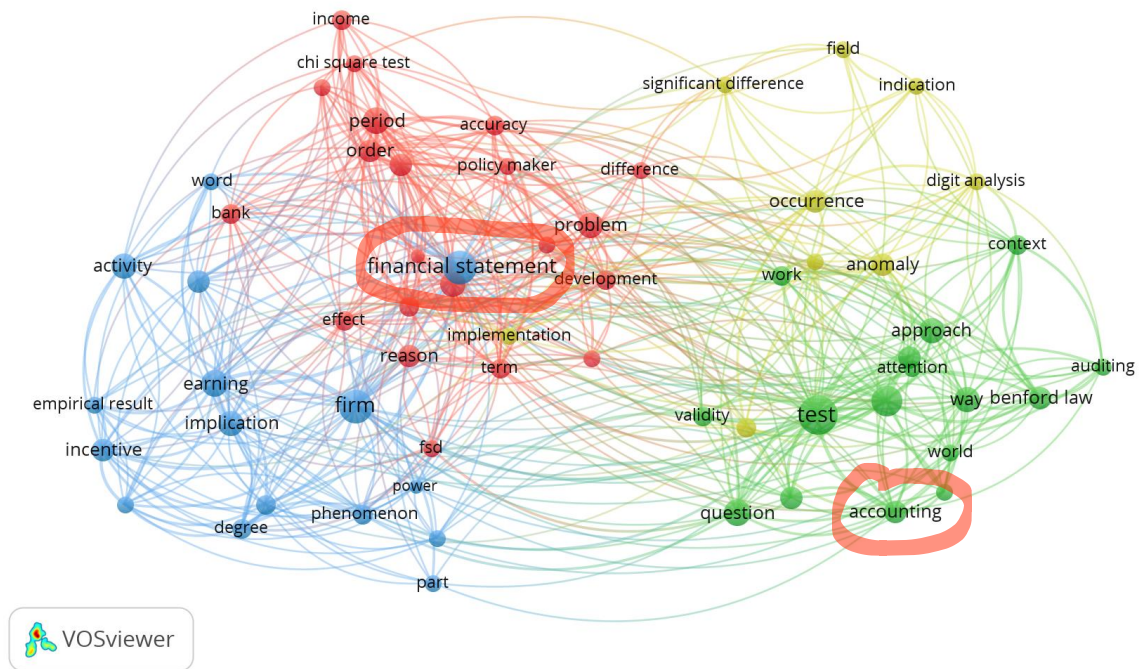


**Figure 1.** Benford's law in scientific disciplines – WoS  
Source: WoS, accessed September 2021

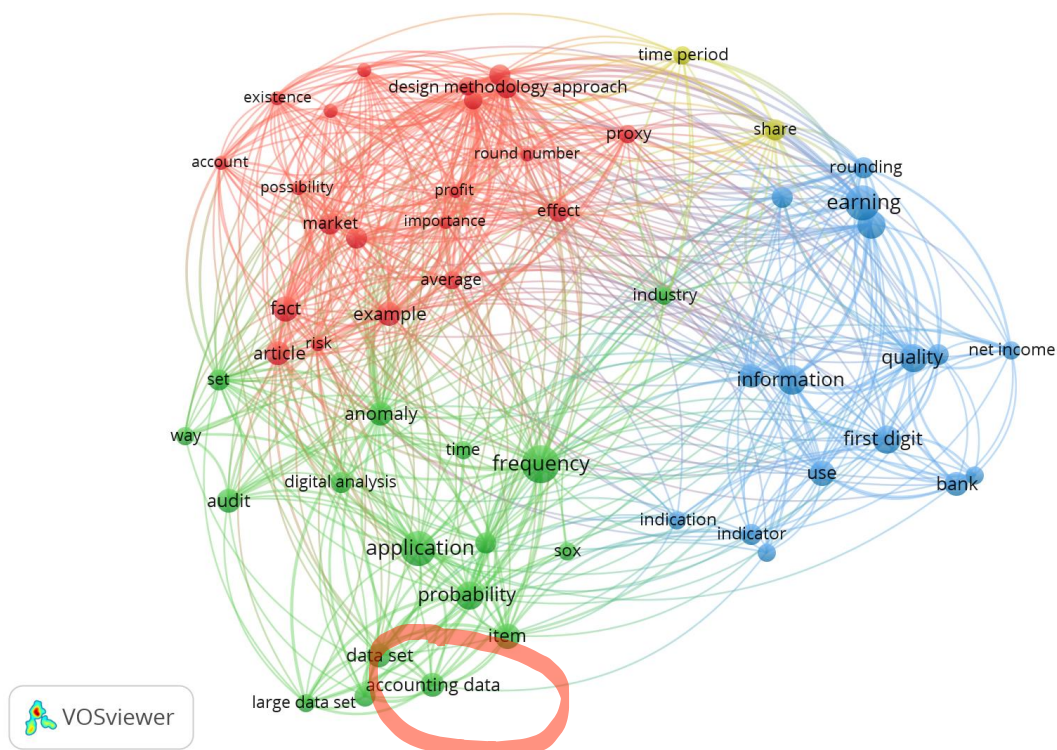
The literature analysis also includes an analysis of the connections between words in the abstracts of manuscripts from particular areas of science. The authors focused on the abstract analysis because the number of words is strictly limited in manuscript titles or keywords. Using the VoSviewer tool, the links between the phrases used in the abstracts were indicated. Figure 2 shows the relationship of words in the Economics area.

The Economics area represents the most significant number of manuscripts. For this reason, it has the highest number of words. The words "accounting" and "financial statement" appeared in the abstracts. These words appeared in two separate thematic clusters. Therefore, it can be concluded that Benford's Law is used in accounting, but the word 'Inventories' has not been found.

In Business Finance (Figure 3), financial data developed by the accounting system was used. Similarly, there is no inventory analysis in this area.



**Figure 2.** Analysis of the words of abstracts in the Economics area.  
Source: own study based on WoS, using Vosviewer



**Figure 3.** Abstract word analysis in the area of Business Finance  
Source: own study based on Web of Science, using Vosviewer





Using Benford's law, the reliability of financial information was tested by Jianu and Jianu (2021). The authors examined the impact of IFRS implementation on the credibility of financial statements for balance sheet items: receivables, liabilities, and net financial results. The research results of Jianu and Jianu (2021) indicate that the lack of fit of the empirical distribution with the Benford distribution does not mean a fraud and may result from the nature of the variables.

Benford's law is used to research phenomena related to frauds made during general elections, medical research, or tax avoidance. The undervaluation of Benford's Law in medical science is noted by Pollah et al.. The authors point out that Benford's Law can be used in clinical analyses.

### 3 Methodology and data sample

The Thomson Reuters Eikon database was used in the study. The selection of the database results from the availability of specific financial data in it, which is not available, for example, in the Orbis BvD or Sabi BvD database. These data will be used in further research on the application of Benford's Law in accounting and relate to, among other things, accruals, other operating income and expenses. The Thomson Reuter Eikon database was also used in research on the application of Benford's Law to assess the reliability of financial data of Romanian-listed companies (Jianu & Jianu, 2021).

The Thomson Reuters Eikon database (accessed May 20, 2022) obtained 14,553 public and private companies after selecting the Country of Headquarters - Portugal. Then, the number of companies in individual sectors was checked for the balance sheet item of inventories in 2020 (Inventories > 0). Thus, the sample was limited to 9,889 companies. A clear division of companies into sectors for the criterion of inventory value greater than zero in 2020 is presented in Table 1. Due to data acquisition from the Thomson Reuters Eikon database, the division into sectors was carried out using the Refinitive Business Classification (TRBC) classification.

Companies from the following sectors will be qualified for further analysis:

- Basic Materials
- Consumer Cyclicals
- Consumer Non-Cyclicals
- Industrials
- Real Estate

The final research sample for Benford's first digit test analysis covers 8,336 companies.

The analysis of digit distribution following Benford's Law requires certain conditions to be met. The studied phenomena cannot have boundary values (minima and maxima) introduced by man. The second criterion is the lack of embedded digits in the analysed values assigned to the sequential number (e.g., invoice numbers or bank account numbers with encoded information). The third condition is a sufficiently large research sample.

**Table 1.** Division of the research sample by sectors of economic activity.

| Industry sector                            | Number of companies |
|--------------------------------------------|---------------------|
| Academic & Educational Services            | 31                  |
| Basic Materials                            | 1177                |
| Consumer Cyclical                          | 2436                |
| Consumer Non-Cyclical                      | 2250                |
| Energy                                     | 451                 |
| Financials                                 | 32                  |
| Government Activity                        | 4                   |
| Healthcare                                 | 255                 |
| Industrials                                | 1772                |
| Institutions, Associations & Organizations | 4                   |
| Real Estate                                | 701                 |
| Technology                                 | 273                 |
| Utilities                                  | 128                 |
| N/A                                        | 375                 |
| Total                                      | 9889                |

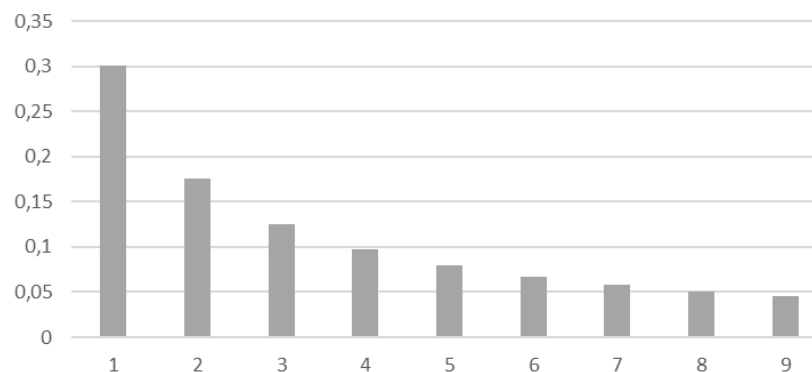
Source: own study based on Thomson Reuters Eikon

The Benford distribution can be described by the following formula (Nigrini, 2012) :

$$BL(d) = \log\left(1 + \frac{1}{d}\right) \quad (1)$$

where: d - number of digits

The Benford distribution can be applied to different digits in a number. This study focuses on the most commonly used first digit test. Only the first digit from the left will be analysed, with values from 1 to 9. A graphic illustration of the Benford distribution for the first digit is shown in Figure 5.

**Figure 5.** Benford distribution, first digit test

Source: own study based on Nigrini (2012)

It can be noticed in the literature that many measures determine the fit of the empirical distribution with the theoretical one. A commonly used measure of distribution fit is Mean Absolute Deviation - MAD. The formula for MAD is as follows (Nigrini, 2012):

$$MAD = \frac{1}{n} \sum_{i=1}^n |x_i - m(X)| \quad (2)$$

where:             $m(X)$  - average value of the data set  
                       $n$  - number of data values  
                       $x_i$  - data values in the set

The MAD value determines the degree of matching of the distributions. MAD values in the range  $<0 - 0.006$ ) indicate a close fit of the analysed distributions. MAD values in the range  $<0.006 - 0.012$ ) indicate an acceptable fit of the analysed distributions. MAD values in the range  $<0.012 - 0.015$ ) indicate a marginally acceptable fit of the analysed distributions. The MAD value above 0.015 means that the distributions are not fit.

#### 4 Research results

Stocks of materials and goods are valued at the balance sheet date at purchase prices, i.e. historical transaction prices, not greater than their net selling price. In calculating the cost of finished products, we also have their value expressed in the costs of expenditure incurred for their production. Due to the valuation requirements for accounting purposes, these values should be consistent with Benford's theoretical distribution in the first digit test.

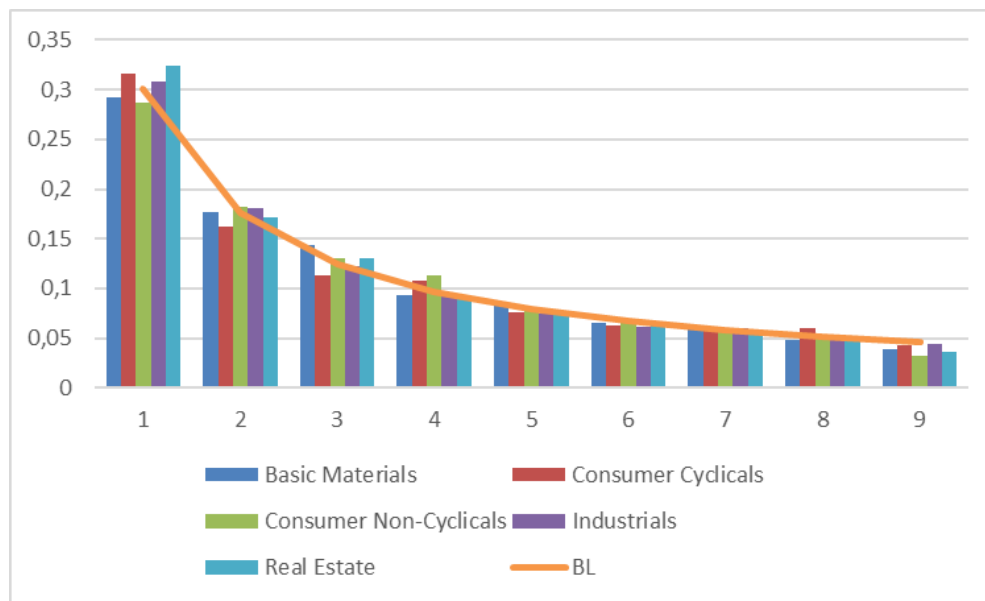
The analysis will be carried out five years back, starting from the last financial year, 2020. We selected economic activity sectors with at least 500 Portuguese companies in the study. Figure 6 shows the first digit test for the fiscal year 2016. In the graphs, the BL line corresponds to the Benford theoretical distribution, while the bars indicate the first digit test results for the relevant sectors of economic activity.

The fit of empirical distributions for individual sectors is measured based on MAD.

Based on Table 2, it can be concluded that the adjustment of the empirical and theoretical distribution for all analysed sectors was at least at an acceptable level.

Figure 7 shows the first digit test for the 2017 fiscal year.



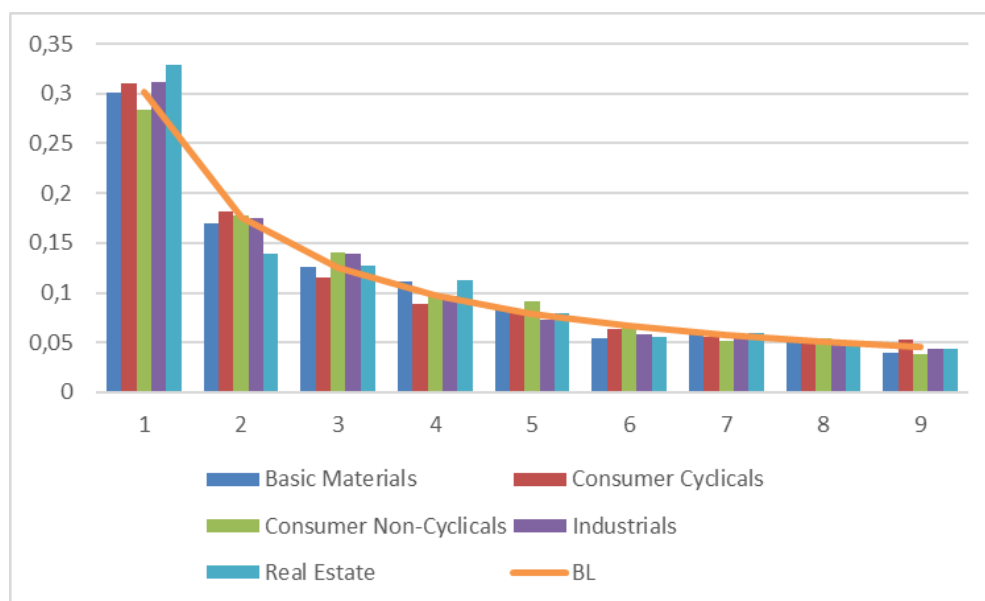


**Figure 6.** Benford's first digit test for 2016  
Source: own study based on data from Thomson Reuters Eikon

**Table 2 -** Mean Absolute Deviation for Benford first digit test for 2016

| Basic Materials | Consumer Cyclical | Consumer Non-Cyclical | Industrials | Real Estate |
|-----------------|-------------------|-----------------------|-------------|-------------|
| 0.00535         | 0.00790           | 0.00658               | 0.00358     | 0.00653     |

Source: own study based on data from Thomson Reuters Eikon



**Figure 7.** Benford's first digit test for 2017  
Source: own study based on data from Thomson Reuters Eikon

The fit of empirical distributions for individual sectors is measured based on MAD. Table 3 shows the MAD values for selected sectors.

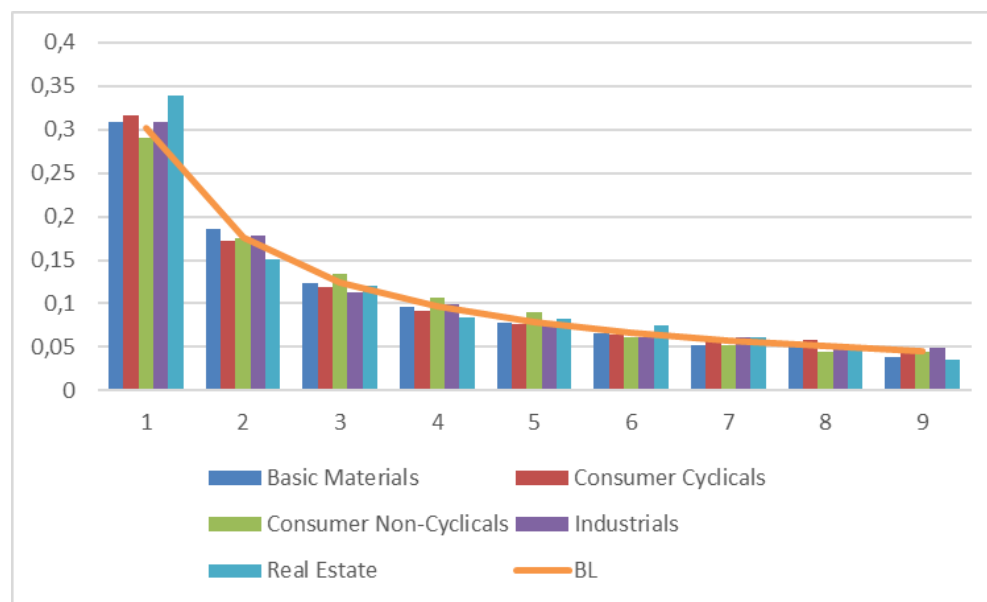
Based on Table 3, it can be concluded that the adjustment of the empirical and theoretical distribution for all analysed sectors was at least at an acceptable level.

**Table 3** - Mean Absolute Deviation for Benford first digit test for 2017

| Basic Materials | Consumer<br>Cyclicals | Consumer Non-<br>Cyclicals | Industrials | Real Estate |
|-----------------|-----------------------|----------------------------|-------------|-------------|
| 0.00558         | 0.00583               | 0.00762                    | 0.00532     | 0.01099     |

Source: own study based on data from Thomson Reuters Eikon

Figure 8 shows the first digit test for fiscal 2018.



**Figure 8.** Benford's first digit test for 2018

Source: own study based on data from Thomson Reuters Eikon

The fit of empirical distributions for individual sectors is measured based on MAD. Table 4 shows the MAD values for selected sectors.

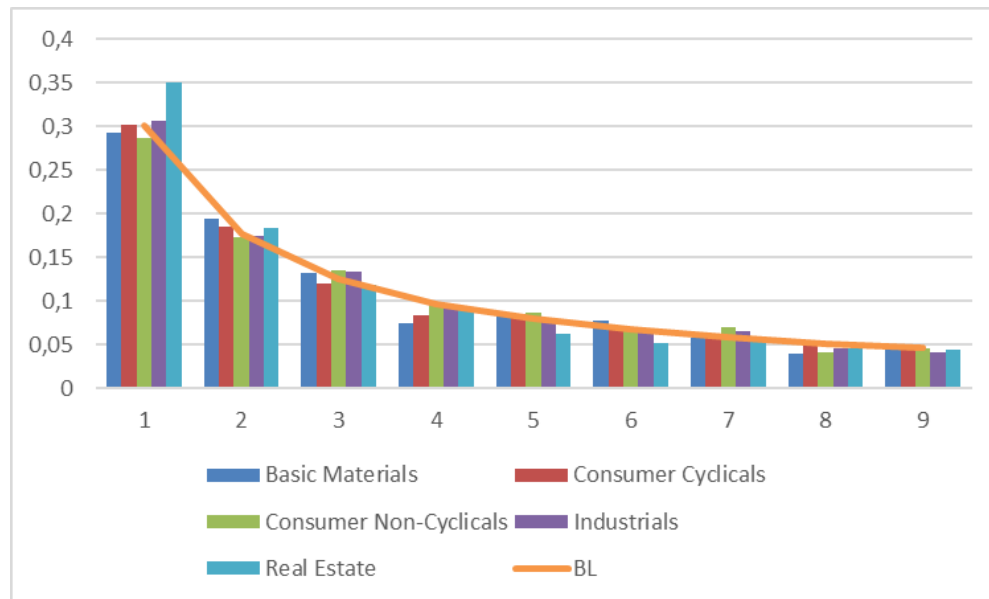
**Table 4** - Mean Absolute Deviation for Benford first digit test for 2018

| Basic Materials | Consumer<br>Cyclicals | Consumer Non-<br>Cyclicals | Industrials | Real Estate |
|-----------------|-----------------------|----------------------------|-------------|-------------|
| 0.00425         | 0.00531               | 0.00688                    | 0.00443     | 0.01191     |

Source: own study based on data from Thomson Reuters Eikon

Based on Table 4, it can be concluded that the adjustment of the empirical and theoretical distribution for all analysed sectors was at least at an acceptable level. It can also be noticed that the MAD value for the Real Estate sector is growing year by year, and in Table 4, it is already on the verge of an acceptable match (the acceptable conformity level is 0.012).

Figure 9 shows the first digit test for the 2019 financial year.



**Figure 9.** Benford's first digit test for 2019

Source: own study based on data from Thomson Reuters Eikon

The fit of empirical distributions for individual sectors is measured based on MAD. Table 5 shows the MAD values for selected sectors.

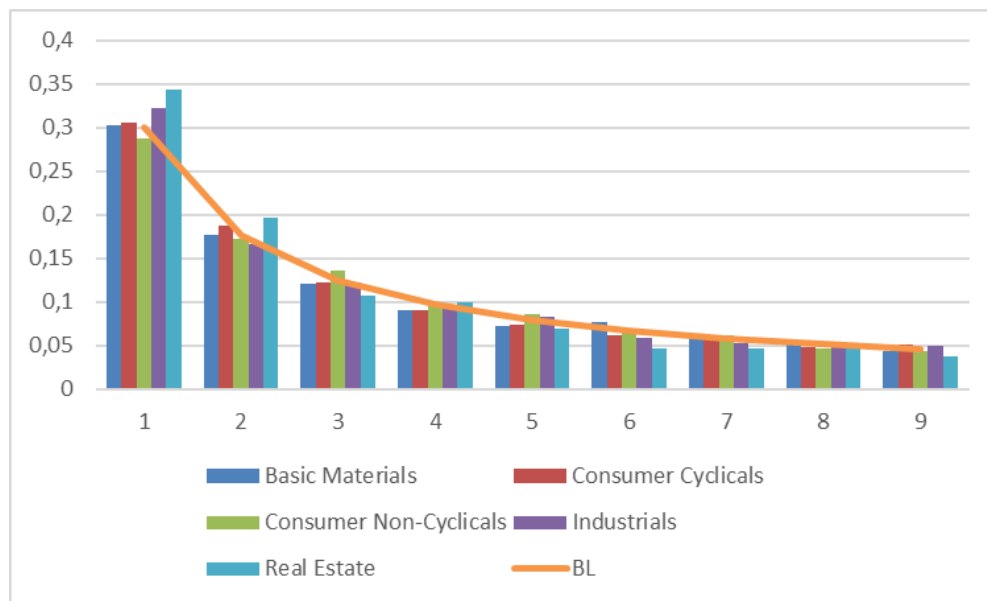
**Table 5 -** Mean Absolute Deviation for Benford first digit test for 2019

| Basic Materials | Consumer Cyclical | Consumer Non-Cyclical | Industrials | Real Estate |
|-----------------|-------------------|-----------------------|-------------|-------------|
| 0.00950         | 0.00422           | 0.00691               | 0.00475     | 0.01235     |

Source: own study based on data from Thomson Reuters Eikon

Based on Table 5 it can be concluded that for the analysed sectors (except for the Real Estate sector), the empirical and theoretical distribution adjustment was at least at an acceptable level. It can also be noticed that the MAD value for the Real Estate sector exceeded the value of 0.012, which is the limit value of an acceptable match.

Figure 10 shows the first digit test for the fiscal year 2020.



**Figure 10.** Benford's first digit test for 2020

Source: own study based on data from Thomson Reuters Eikon

The fit of empirical distributions for individual sectors is measured based on MAD. Table 6 shows the MAD values for selected sectors.

**Table 6 -** Mean Absolute Deviation for Benford first digit test for 2020

| Basic Materials | Consumer Cyclical | Consumer Non-Cyclical | Industrials | Real Estate |
|-----------------|-------------------|-----------------------|-------------|-------------|
| 0.00437         | 0.00483           | 0.00575               | 0.00629     | 0.01482     |

Source: own study based on data from Thomson Reuters Eikon

Based on Table 6, it can be concluded that for the analysed sectors (except for the Real Estate sector), the empirical and theoretical distribution adjustment was at least acceptable. It can also be noticed that the MAD value for the Real Estate sector exceeded the value of 0.012, which is the limit value of an acceptable match. For the real estate sector, the trend of mismatching has deepened, indicating problems with the valuation of inventories in this sector.

The presented statements indicate anomalies in the frequency of occurrence of digits in some sectors. Benford's first digit test does not report fraud but reveals potential abnormalities. In the case of the assets (Inventories) analysed in this article, which are subject to the same valuation as in terms of measurement methods and the scope of the disclosure in the analysed sectors, the divergent values are interesting mainly for companies from the Real Estate sector.

## 5 Conclusions

The quality of financial data in financial statements is becoming increasingly important. In times of digitisation and quick access to data, manipulating financial information can quickly transfer the intended results. The activity of economic units both nationally and globally, through a network of connections, can be compared to a living organism. Each enterprise is a sender and receiver of financial information. The concluded purchase and sale transactions result in the financial statements of entities participating in the transactions.

The article aims to check whether the financial data disclosed by companies comply with natural laws regarding the resources used. The tool that verifies the natural nature of financial data is Benford's Law. Benford's law in economic sciences is used primarily to analyse fraud and manipulation in corporate taxation. The effectiveness of this anomaly detection tool, proven in publications, can be adapted to the accounting needs and assessment of the quality of financial data in individual sectors of economic activity.

An analysis of Portuguese companies for the period 2020-2016 shows that Benford's Law can be used to analyse the quality of financial information in terms of inventory disclosure in the balance sheet. Based on a research sample covering almost 9,000 companies, we could only show that the Benford first digit test did not show the convergence of distributions in one sector. The reasons for the non-compliance of the distributions in the Real Estate sector will be the subject of further research.

The limitation of the paper concerns the data selection. We used the Eikon database with the financial figures of Portuguese companies. We also plan to develop the research using Orbis or Sabi database. Additionally, some authors state that financial statement fraud should be detected using a second-digit test (Pavlović et al., 2019). We plan to develop our research on the second digit test as well.

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