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OVERSIGHT OF GOVERNMENT SPENDING ON COMBATING COVID-19: APPLICATION OF THE NEWCOMB-BENFORD LAW IN PUBLIC EXPENDITURE EXECUTION

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ABSTRACT

The research aims to analyze the federal government's expenditures in 2020 and 2021 related to combating the COVID-19 pandemic in search of fraud indicators. This period was characterized by a sudden increase in public spending, accompanied by less stringent procurement processes. The Newcomb-Benford Law describes the frequency of leading digits in datasets and is presented as an effective tool for identifying anomalies and fraud in financial records, being widely explored in various fields, particularly in audits and accounting. A comparison was made between the observed and expected frequencies for the first, second, and first two digits of the committed values, segregated by year or procurement method. The analysis was conducted through graphs and statistical tests to verify the adherence of distributions to the Newcomb-Benford Law. Commitments made in 2020 showed better adherence than those in 2021, suggesting a higher probability of manipulations or fraud in the second year of the pandemic. Additionally, expenditures resulting from bidding processes were more compliant when compared to non-bid expenditures, confirming the perception that there is a higher likelihood of manipulation or fraud in non-bid spending. The research reveals indications that can be interpreted as warnings for oversight and control bodies, with the proposed approach serving as a mechanism for auditing government expenditures, assisting in the selection of samples that require detailed analysis by auditors and investigator.

Keywords: Newcomb-Benford Law. Fraud. Pandemic. Covid-19.

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1 INTRODUCTION

The COVID-19 pandemic sparked discussions regarding the management of government spending arising from a public health emergency. The demands for resources to tackle the health crisis led to billions of reais being urgently spent, in an unprecedented manner in recent history (Edejer et al., 2020).

In order to authorize such spending, in May 2020, the National Congress enacted Constitutional Amendment No. 106, which eased fiscal, administrative, and financial rules during the public calamity caused by the novel coronavirus. The new amendment established a specific budget for pandemic-related expenses, allowing the creation of expenditures without the usual bureaucratic hurdles, exempted the Executive Branch from complying with the "golden rule," and simplified the process of procurement and personnel hiring (Câmara dos Deputados, 2020).

As a result, it is plausible to believe that COVID-19 opened the doors to the inefficient use of public resources and corruption, as more funds had to be made available to deal with the emergency. This was accompanied by increased discretion in decision-making processes, especially in resource allocation, followed by negligence in controls, lax accountability, and a diminished commitment to transparency (Anessi-Pessina et al., 2020; Qin et al., 2021). In this context, it becomes crucial to implement methodologies that can assist public managers in identifying fraud and mismanagement of public resources, especially during emergency periods (Oliveira & Silva, 2024).

Among the methodologies for analyzing samples of expenditures directed at combating the pandemic, the technique proposed by the Newcomb-Benford Law (NBL) stands out. This method has been widely used as a tool to detect fraud in various cases involving income tax returns (Nigrini, 1999), corporate accounting systems (Carslaw, 1988; Maher & Akers, 2002), and the application of public resources (Santos et al., 2005; Costa et al., 2012; Ganassin et al., 2016; Rodrigues et al., 2023; Oliveira & Silva, 2024).

Therefore, considering the high volume of expenditures made by the federal government to combat the COVID-19 pandemic in Brazil (Pereira et al., 2023) and the need for social oversight of the use of public resources during the period of regulatory relaxation brought by provisional measures to address the pandemic (Oliveira & Silva, 2024), this research presents the following question: Are there signs of fraud in federal government expenditures in 2020 and 2021 related to combating the COVID-19 pandemic?

Based on this question, the present study aims to analyze federal government expenditures in 2020 and 2021 related to combating the COVID-19 pandemic in search of indications of fraud. This analysis is conducted from the perspective of the conformity of commitment values with the Newcomb-Benford Law (NBL).

For this purpose, expenditures from 2020 and 2021 were selected, specifically under budget action 21C0 (Addressing the Public Health Emergency of International Concern Arising from the Coronavirus), which contains the highest number of commitments and the most detailed information on the expenditures made (Lima et al., 2021).

The relevance of this study lies in the detailed analysis of the federal government's direct spending in combating the COVID-19 pandemic, as opportunities for fraudulent acts can arise during times of public expenditure flexibility, such as during crises. In the context of a significant increase in public spending during the health emergency and the relaxation of procurement processes, the application of the Newcomb-Benford Law becomes crucial for analyzing financial conformity. The approach proposed in this study can be adopted as an effective mechanism for selecting audit samples in oversight work and even criminal investigations, contributing to strengthening transparency and integrity in government financial management.

This study offers significant contributions in the social, academic, and professional spheres, highlighting its importance and relevance.

Socially, the research reinforces transparency and oversight in the use of public resources, which is necessary in times of public calamity, preventing mismanagement and the occurrence of corrupt acts. Academically, the research aims to enrich discussions in the field of government auditing by applying the Newcomb-Benford Law (NBL) to detect potential fraud in large volumes of financial data, contributing to the methodological advancement in the analysis of public spending. Professionally, the study can serve as a practical guide for public managers and auditors, providing concrete tools for efficient oversight and resource control in emergency situations, ensuring the ethical and effective use of public resources.

2 THEORETICAL FRAMEWORK

2.1 Fraud and *red flags*

Fraud can be defined as an intentional act carried out for personal gain by an agent to the detriment of others, taking advantage of the path of least resistance (Cella & Rech, 2017). According to Singleton and Singleton (2010), there are various definitions of fraud, related to terms such as crime, corporate fraud, management fraud, occupational fraud, among others. Fraud is often detected through intuition, suspicion from investigators, managers, auditors, or through an exception or anomaly in financial records.

Thus, fraud is difficult to detect because it is deliberately carried out through the manipulation of information to varying degrees, employing some degree of realism. Therefore, its identification comes from the recognition of suspicious signs, also known in the literature as red flags (Sandhu, 2022).

The use of red flags serves as a guide and foundation for developing more comprehensive and robust audit and evaluation strategies. A technique that has been increasingly explored and studied in recent years is the Newcomb-Benford Law (NBL) (Nigrini, 2012; Gonçalves et al., 2023). The NBL will be further explored in the following subsection.

2.2 Fraud Detection and the Newcomb-Benford Law

The Law of Anomalous Numbers was discovered by the astronomer and mathematician Simon Newcomb in 1881 (Newcomb, 1881). His studies concluded that the occurrence of the first digit (the leftmost digit of a number) followed a logarithmic distribution. Since then, the law has been tested in many fields of knowledge (Orth et al., 2020).

Contrary to the common assumption that the digits 1 to 9 would have the same probability of appearing in the first position of a series of numbers, Newcomb (1881) observed that, in fact, this frequency was decreasing, based on the observation of logarithmic tables. At the time, these tools were used for performing multiplications, and by noticing that the first pages, which represented the smaller digits, were more worn out, he realized that they were used more often than the pages with larger numbers. Newcomb (1881) concluded that the probability of the occurrence of the first digits in a series of values derives from the fact that the mantissas, or the decimal part of their logarithms, follow a uniform distribution.

Although Newcomb did not present statistical evidence for his discovery, physicist Frank Benford rediscovered the phenomenon in 1938 through empirical evidence based on digit frequencies from twenty different tables, which included various data, such as: surface areas of rivers, heat content of thousands of chemical compounds, and tables of square roots (Benford, 1938). The combination of these tables surprisingly matched the expected frequencies predicted by Newcomb. Therefore, these frequencies became known as the Newcomb-Benford Law (NBL) or the First Digit Law (Hill, 1995).

A particular feature of the Newcomb-Benford Law (NBL) is its scale invariance, as emphasized by Pinkham (1961), who showed that multiplying the data by a scale factor does not alter the probability distribution. The digits that occur with logarithmic probability are the only ones that maintain their probability of occurrence when multiplied by a factor (Varian, 1972). Additionally, Hill (1988) conducted experiments demonstrating that when people invent random numbers, those numbers never conform to the NBL, even though they may share some of the law's properties.

Cunha and Bugarin (2014) offer a practical explanation of the frequency differences in NBL using the example of a 10,000-reais investment in a pension fund that offers a fixed return of 7% per year. Such an investment doubles in value approximately every 10 years. Thus, after 10 years, with 1 as the first digit, the amount will reach 20,000 reais, and over the next 10 years, the amount will double to 40,000 reais (during this period, the numbers 2 and 3 will appear as first digits). After another decade, the amount will be 80,000 reais (with digits 4, 5, 6, and 7 appearing over the same 10 years). At some point, the value will reach 100,000 reais, with the digit 1 recurring for another 10 years. Therefore, when choosing a random date, it is more likely that the value of the investment on that day will have 1 as the first digit (Cunha & Bugarin, 2014).

According to Nigrini (2012), although Benford did not provide guidance on which datasets should follow the expected frequencies, there are references to natural events and phenomena related to science. Furthermore, the general rule is that the analyzed dataset should have at least 1,000 records before good conformity with the NBL can be expected.

Additionally, there are some conditions for a sequence of data to be considered suitable for testing under the NBL: its values should represent the magnitude of facts or natural events; the sample should not be small or exhibit small variations; the range of values should be broad, with no limitations on minimum or maximum values; the data should not refer to identification numbers (such as social security numbers, bank account numbers, or flight numbers); the data should not be influenced by psychological factors, such as prices ending in .99; and the data should have a mean greater than the median, indicating positive skewness, meaning that they should not be too clustered around the average (Nigrini, 1999; Durtschi et al., 2004; Goodman, 2016).

2.3 Previous Studies

Several studies have already been conducted addressing the topic of fraud in the fields of auditing and accounting (Carslaw, 1988; Nigrini, 1999; Nigrini, 2000; Jošić & Žmuk, 2018; Orth et al., 2020). Specifically regarding studies on indications of irregularities in the execution of public expenditures, notably in the amounts of commitment notes, liquidation notes, or payment orders, the works of Santos et al. (2005), Costa et al. (2012), Ganassin et al. (2016), Cella and Zanolla (2018), Da Cruz et al. (2021), Rodrigues et al. (2023), Silva and Boente (2023), and Oliveira and Silva can be cited (2024).

Santos et al. (2005), with the aim of proposing a model for the field of Financial Accounting and Digital Auditing, identified that the Newcomb-Benford Law was able to capture the behavior of public expenditures in twenty municipalities in the State of Paraíba, thus demonstrating that this method was effective in indicating the strong likelihood of overpricing and splitting of public expenses.

Costa et al. (2012) aimed to detect deviations in the distribution of the first and second digits of state public expenditures according to the Newcomb-Benford Law by analyzing 134,281 commitment notes issued by 20 Managing Units in two states. In their findings, Costa et al. (2012) found significant deviations in the distribution of digits: an excess occurrence of 7 and 8, and a shortage of 9 and 6, indicating a tendency to avoid bidding processes.

Ganassim et al. (2016), aiming to apply a model based on the Newcomb-Benford Law (NBL) as a tool for social control, analyzed 7,037 commitment notes from the Public Prosecutor's Office of the Federal District and Territories (MPDFT) and the Military Public Prosecutor's Office

(MPM). They observed the existence of some deviations from what was expected by the NBL, particularly in non-bid procurements.

The study conducted by Cella and Zanolla (2018) aimed to analyze the relationship between municipal transparency and the application of the Newcomb-Benford Law in the expenditure execution process in two municipalities in the state of Goiás. Their findings indicate that the more transparent municipality showed greater conformity with the Newcomb-Benford Law, while the less transparent municipality exhibited greater differences between expected and observed frequencies, with a higher probability of irregularities in expenditure execution.

Da Cruz et al. (2021), aiming to analyze fraud through the application of the Newcomb-Benford Law to the disbursements made by senators of the Federal Republic of Brazil, identified a probable existence of fraud, manipulation, or errors, highlighting which documents should be evaluated by public expenditure control teams.

The study by Rodrigues et al. (2023) aimed to investigate the behavior of committed expenditures from 399 municipalities in Paraná through the lens of the Newcomb-Benford Law (NBL). The main finding of the research shows that the majority of municipalities were not in compliance with the NBL, demonstrating that high variability raises red flags about these public expenditures, thus alerting to the possibility of errors or fraud.

Silva and Boente (2023), in analyzing the accounting compliance of budgetary and asset expenditures of the Federal Network of Professional and Technological Education using the Newcomb-Benford Law, observed distortions in values, possibly associated with errors, fraud, or particular characteristics of the transactions. Thus, Silva and Boente (2023) point to the possibility of using the NBL as an important technique in auditing work within the federal network.

Finally, Oliveira and Silva (2024) used the Newcomb-Benford Law to analyze the bid values from electronic auctions in all Brazilian states in the context of public governance. They observed anomalies in the analysis of the first and second digits in some states, indicating possible irregularities or deviations. The findings by Oliveira and Silva (2024) suggest that the methodology facilitates decision-making by public managers to identify fraud and mismanagement of public resources.

It is worth noting that the NBL has proven to be an applicable tool in all these studies, confirming its usefulness as an indicator of the occurrence of fraud. It is evident that this methodology has been adopted for many years and continues to advance in research to this day. Therefore, considering the utility of the NBL in signaling warnings of fraud occurrence, this research will use this method, as demonstrated in the following section.

3 METHODOLOGICAL PROCEDURES

3.1 Data Selection and Collection

The research database was built from commitment notes issued in 2020 and 2021, linked to Action 21C0 (Addressing the Public Health Emergency of International Concern Arising from the Coronavirus), comprising a set of 68,982 commitment notes with a total value of approximately R$ 67 billion. This amount stems from extraordinary budgetary credits opened through provisional measures by the Federal Executive Branch submitted to the National Congress.

The documents were obtained from the Advanced Management Budget Information System (SIGA Brasil) (SigaBrasil, 2022). This system provides federal budget information and is maintained by the Information Technology Secretariat, which facilitates access to data from the Integrated Financial Administration System (SIAFI) and other public budget databases.

The search for commitment notes in SigaBrasil was conducted based on the selection of relevant variables using the Web Intelligence tool available in the data repository. The data sets of interest were selected, which in this case were the expenditure executions of the 2020 and 2021

Annual Budget Law (LOA). From this point, variables of interest were selected: Federation Unit, Locality, Budget Unit, Action, Expenditure Element, Credit Type, Commitment Note, Year of Commitment Issuance, Application Modality, Bidding Modality, among others. Commitment measures, such as committed, liquidated, and paid amounts, were then captured.

To capture only the commitment notes for Action 21C0, a search filter was included for this action, considering only positive values. The amounts committed under budget action 21C0 were R$ 47.11 billion in 2020 and R$ 20.51 billion in 2021.

It was found that the data from fund-to-fund transfers to municipalities showed an excess of duplicate values. This is due to the rules for carrying out these transfers, which result in several municipalities with similar characteristics receiving equal amounts. Such a finding contradicts the conditions for the data to follow a Newcomb-Benford distribution, which requires data to be naturally generated without imposed rules that skew the expected proportions. Therefore, these transfers were excluded from the database used in the analyses of this study.

Additionally, other transfers were excluded, considering only expenses in the direct application modality and direct application in intra-budgetary operations, which primarily correspond to the acquisition of goods and services from suppliers. This set of commitment notes was chosen because transfers to other entities merely constitute decentralization of resources and are not the focus of this study.

Furthermore, for the tests on the first two digits, only expenditures with values equal to or greater than R$ 10.00 were selected for analysis. After all exclusions, the database consisted of 40,108 commitment notes, totaling R$ 27,875,816,786.15.

Since the objective was to verify whether expenditures made through bidding procedures would show greater conformity compared to those resulting from direct contracting, Table 1 was created with the values of the commitment notes from direct application, segregated by year and bidding modality, allowing for a better understanding of the analyzed data set.

Table 1

Commitment Notes Classified by Year and Bidding Modality

Modality	2020		2021		Total	
	Amount	Qty.	Amount	Qty.	Amount	Qty.
Auction bidding	1.088.295.657,78	20.354	161.026.183,20	1.973	1.249.321.840,98	22.327
Bidding waiver	4.133.029.555,23	13.667	136.842.792,09	424	4.269.872.347,32	14.091
Not applicable	3.565.899.509,01	2.133	18.263.271.002,92	226	21.829.170.511,93	2.359
Non-requirement	272.085.832,78	976	46.765.809,65	65	318.851.642,43	1.041
Fund advance	1.775.184,86	196	42.161,83	15	1.817.346,69	211
Invitation	17.253.854,61	37	57.760.490,74	3	75.014.345,35	40
Competition	69.083.306,06	13	52.484.472,34	7	121.567.778,40	20
RDC	5.555.688,13	13	-	-	5.555.688,13	13
Price taking	4.645.284,93	6	-	-	4.645.284,93	6
Total	**9.157.623.873,38**	**37.395**	**18.718.192.912,77**	**2.713**	**27.875.816.786,15**	**40.108**

Note. Values in Brazilian reais. In 2021, the amount of R$ 18 million includes 46 commitment notes issued to vaccine supplier companies. Source: SigaBrasil (2022).

The selection of the analyzed data considered the need for at least 1,000 records for good conformity in the tests of the first two digits (Nigrini, 2012). Since bidding modalities such as Invitation, Competition, Differentiated Public Contracting Regime (RDC), and Fund Advance are rare in the analyzed data, representing less than 1% of the total commitment notes, it was decided to analyze only auctions for the case of bidding procedures. For direct contracting, the analysis was limited to bidding waivers carried out in 2020, as the 2021 bidding waivers did not meet the

minimum number of recommended records, which was also observed for non-requirements in both years.

Regarding the analysis of conformity for the total number of commitment notes by year, both 2020 and 2021 have a sufficient number of records to verify adherence to the NBL. This data selection is also aligned with Nigrini's (2012) understanding, which emphasizes that the larger the dataset analyzed, the higher the reliability of statistical and non-statistical tests.

When explaining the Newcomb-Benford Law (NBL) to the reader, it is important to highlight that greater adherence means higher conformity of the data with the expected distribution according to the NBL. In other words, greater adherence to the NBL indicates fewer signs of errors or fraud in the distribution. Therefore, the interpretation of the data should take into account that higher adherence represents better conformity of the analyzed numbers.

3.2 Data Analysis

The methodological procedures and tests suggested by Nigrini (2012) and Da Cruz et al. (2021) were used, with the data segregated by year and bidding modality, as in Ganassin et al. (2016). The steps carried out were as follows: i) Segregation of data by year (2020 and 2021) and by bidding modality in 2020 (Auction and Bidding Waiver); ii) Extraction of the digits of interest from each commitment note value (the first, second, and the first two digits); iii) Calculation of the absolute and relative frequencies of each digit; iv) Calculation of the deviations between the observed relative frequency and the expected relative frequency according to the NBL; v) Preparation of graphs containing the observed and expected frequencies for visual analysis of deviations; and vi) Conducting statistical tests and procedures to assess the statistical significance of the deviations and the conformity of the data distribution with the NBL.

It is important to clarify that each commitment note holds the same significance for the analysis, regardless of its amount. Thus, a commitment of R$ 6,376.00 has only its first digit (6), its second digit (3), and its first two digits (63) considered, in the same way as a commitment of R$ 63.00.

Initially, tests were conducted to verify the conformity of the first digits. According to Nigrini (2012), the first-digit test is a high-level test that provides a broader view of the data, being more useful when analyzing smaller datasets, such as around 300 records.

Subsequently, the second digits of the commitments were analyzed. Similar to the first-digit test, this is also a high-level analysis to check the reasonableness of the data, with greater practical utility in specific situations, such as price analysis, election results, inventory counts, or census results, where rounding numbers might indicate some type of anomaly (Nigrini, 2012).

Finally, tests on the first two digits offer a more specific and focused analysis, where potential abnormal duplications or biases in the dataset can be detected. While the first- and second-digit tests analyze the data in a more aggregated manner, the test of the first two digits provides much more information due to its detailed nature, making the combination of the three tests suitable for the proposed investigation (Nigrini, 2012).

The conformity of the data was analyzed through statistical procedures and tests that are divided into:

a) Z-Test: A local test used to measure whether the observed proportion of a specific digit statistically differs from the proportion given by the NBL:

$$Z = \frac{|po - pe| - \left(\frac{1}{2n}\right)}{\sqrt{\frac{pe(1-pe)}{n}}} \quad (1)$$

Where: po = observed proportion; pe = expected proportion; and n = sample size.

b) **Chi-Square Test:** A global test, meaning it checks whether the distribution of the observed

data significantly differs from an expected distribution:

$$\chi^2 = \sum_{i=1}^{k} \frac{(CR-CE)^2}{CE} \quad (2)$$

Where: CR = actual count; and CE = expected count; k = number of digits analyzed, with 9 for the first-digit test, 10 for the second-digit test, and 90 for the first two-digit test.

c) Mean Absolute Deviation (MAD): Does not take sample size into account and is obtained from the average of the absolute deviations calculated for each digit (Nigrini, 2012):

$$MDA = \sum_{i=1}^{K} \frac{|po-pe|}{k} \quad (3)$$

Where: po = observed proportion; pe = expected proportion; and k = number of digits.

d) Sum Test: The sum of all values with the same two leading digits (10, 11, 12...99) in a dataset that follows the NBL is approximately equal, with a proportion of 1/90 or 0.011. While not a proper statistical test, it helps to detect abnormally large transactions when compared to the rest of the data (Nigrini, 2012; Cunha & Bugarin, 2014).

4 RESULTS

4.1 Descriptive Statistics

A descriptive analysis of the data was conducted (Table 2) to verify whether they exhibit the characteristics identified in the literature as favorable to a distribution compatible with the NBL.

Table 2

Descriptive Statistics of Commitment Note Values

Measure	2020	2021	Auction	Bidding Waiver
Mean	244.888,99	6.899.444,49	53.468,39	302.409,42
Median	4.770,00	2.577,80	2.600,00	9.296,00
Mode	2.627,00	5.385,28	1.500,00	2.627,00
Standard Deviation	8.392.338,22	79.334.754,26	844.006,95	11.280.578,08
Skewness	115,15	15,29	67,30	108,30
Minimum	10,02	11,98	10,02	10,89
Maximum	1.284.023.632,94	1.868.420.781,00	78.000.000,00	1.284.023.632,94
Sum	9.157.623.873,38	18.718.192.912,77	1.088.295.657,78	4.133.029.555,23
Count	37.395	2.713	20.354	13.667

Note. The measures for the auction and bidding waiver modalities are limited to the year 2020. Values are in Brazilian reais, except for skewness and count. Source: Prepared by the authors.

Based on the data in Table 2, it is noted that all approaches exhibit the necessary characteristics for the tests, being within wide ranges, with the mean greater than the median and a positive skewness value (Goodman, 2016).

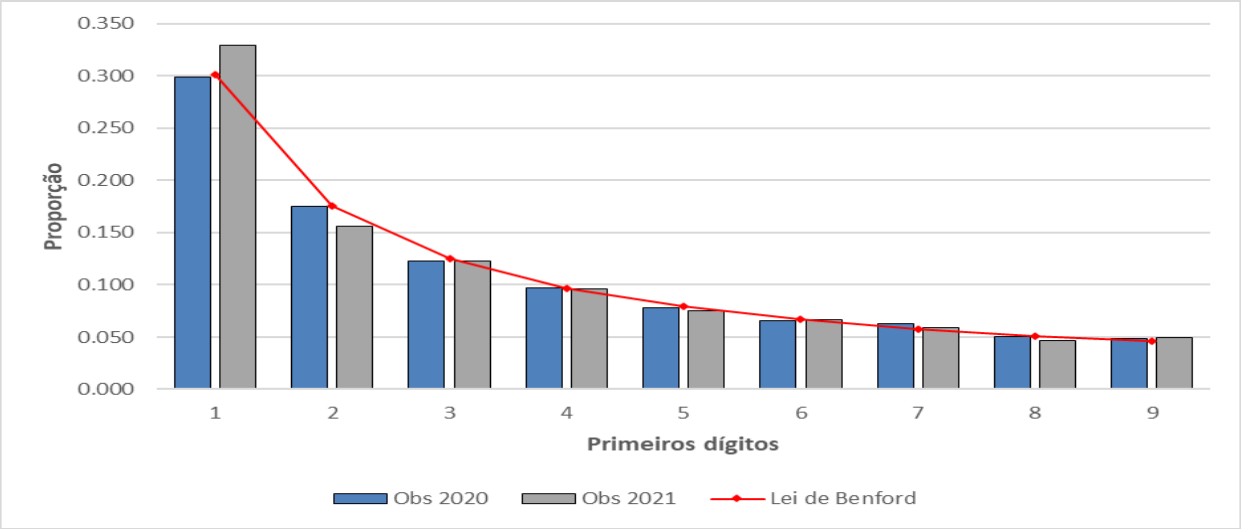
The phenomena studied are expense values (commitment notes) resulting from direct applications related to combating the COVID-19 pandemic, which do not have predetermined value limits and, obviously, are not social records or identification numbers, thus meeting the prerequisites for analysis (Nigrini, 1999).

4.2 Direct Expenditures in 2020 and 2021

This section presents the results for the first, second, and first two digits of direct expenditures in Action 21C0, by year, with the objective of verifying adherence (conformity) to the expected proportions according to the NBL. Graphs illustrate the comparisons of relative frequencies, and a summary of the statistical test results is provided.

Figure 1 shows the observed frequencies for the first digit in the years 2020 and 2021, compared with the expected frequency according to the NBL.

Figure 1
Proportion of the 1st digit for direct expenditures of Action 21C0 in the years 2020 and 2021

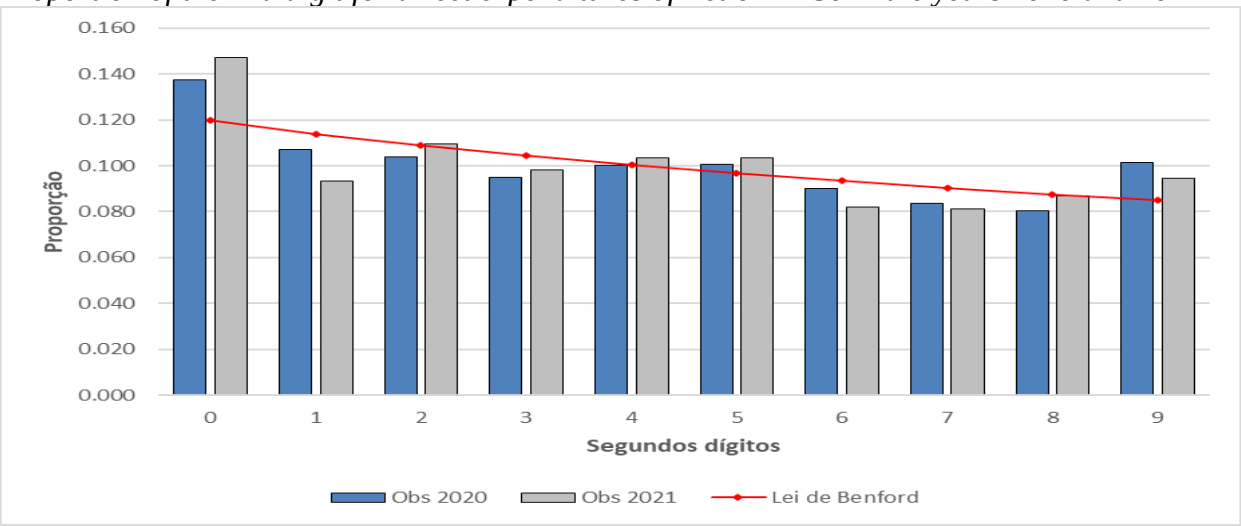


Source: Prepared by the authors.

The graphical analysis of the first digits reveals good adherence between the observed and expected frequencies for 2020. For the year 2021, it is possible to observe a higher-than-expected frequency for digit 1 and a lower-than-expected frequency for digit 2, which will be investigated in the statistical tests.

Figure 2, in turn, presents a graph with the observed frequencies for the years 2020 and 2021, this time for the second digit, along with the expected frequency according to the NBL. The visual analysis shows peaks for digits 0 and 9 for both years analyzed and a slight increase in the observed proportion for 2021 for digits 4 and 5. On the other hand, smaller proportions are observed for digits 1, 2, 3, 6, 7, and 8, with digits 2 and 8 showing smaller proportions only in 2020.

Figure 2
Proportion of the 2nd digit for direct expenditures of Action 21C0 in the years 2020 and 2021

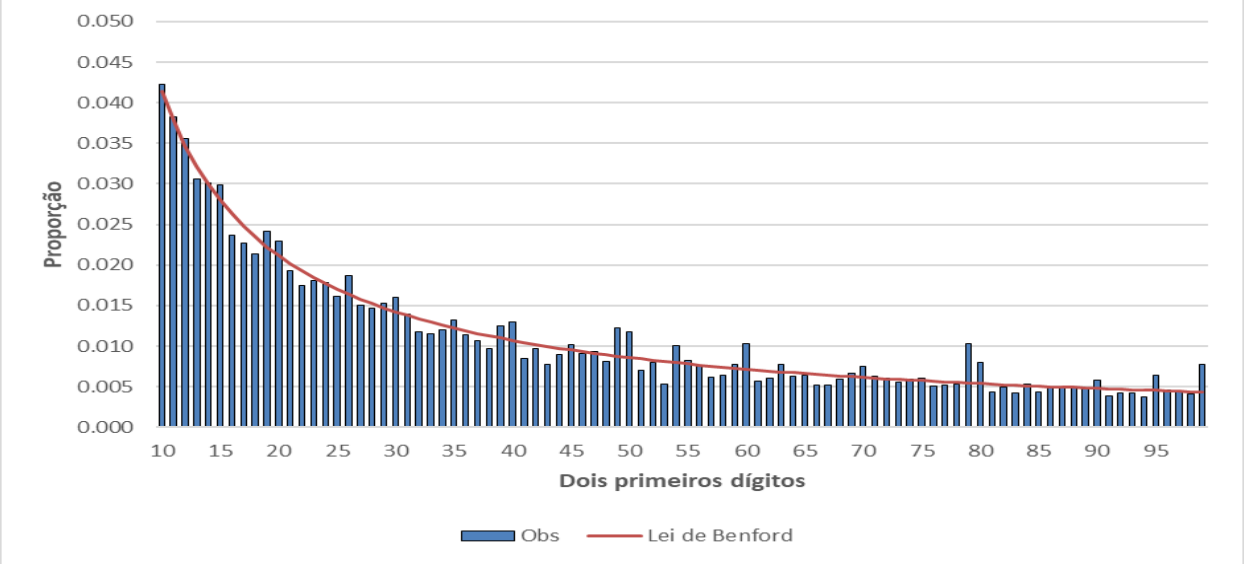


Source: Prepared by the authors.

Figures 3 and 4 provide a graphical illustration of the observed and expected proportions for the first two digits in the years 2020 and 2021, respectively. There is a relative adherence to the NBL proportions in 2020, with some peaks, especially for digits 49, 50, 60, and 79. In 2021, greater deviations can be observed, particularly for digits 10, 15, 53, and 60.

Figure 3

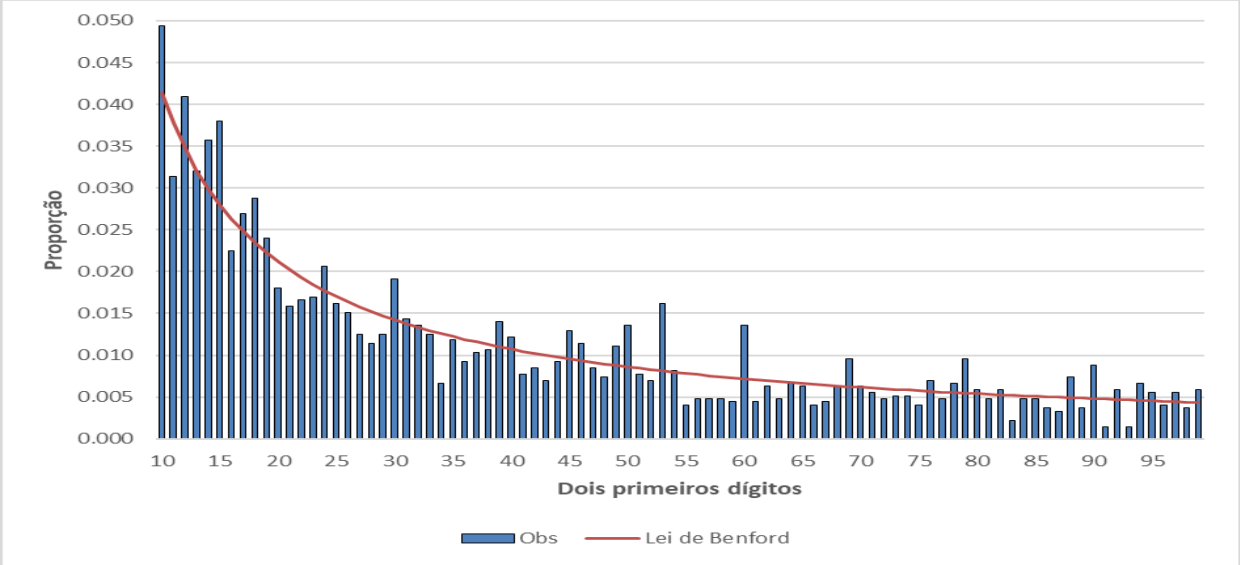
Proportion of the first two digits for direct expenditures in Action 21C0 in 2020



Source: Prepared by the authors.

Figure 4

Proportion of the first two digits for direct expenditures in Action 21C0 in 2021



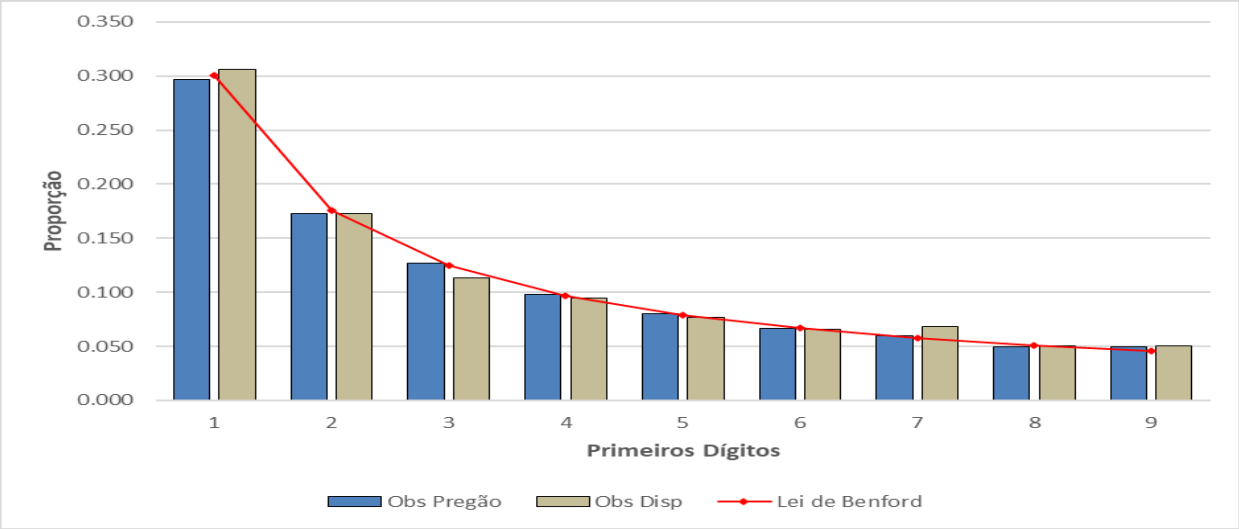
Source: Prepared by the authors.

4.3 Expenditures by Bidding Modality (Year 2020)

This section presents the results for the first, second, and first two digits of direct expenditures in Action 21C0, by bidding modality, in the year 2020, with the analysis limited to the Auction and Bidding Waiver modalities.

Figure 5 shows a graph with the observed and expected frequencies according to the NBL, referring to the first digit observed in the analyzed documents.

Figure 5
Proportion of the 1st digit of direct expenditures in Action 21C0 by bidding modality in 2020

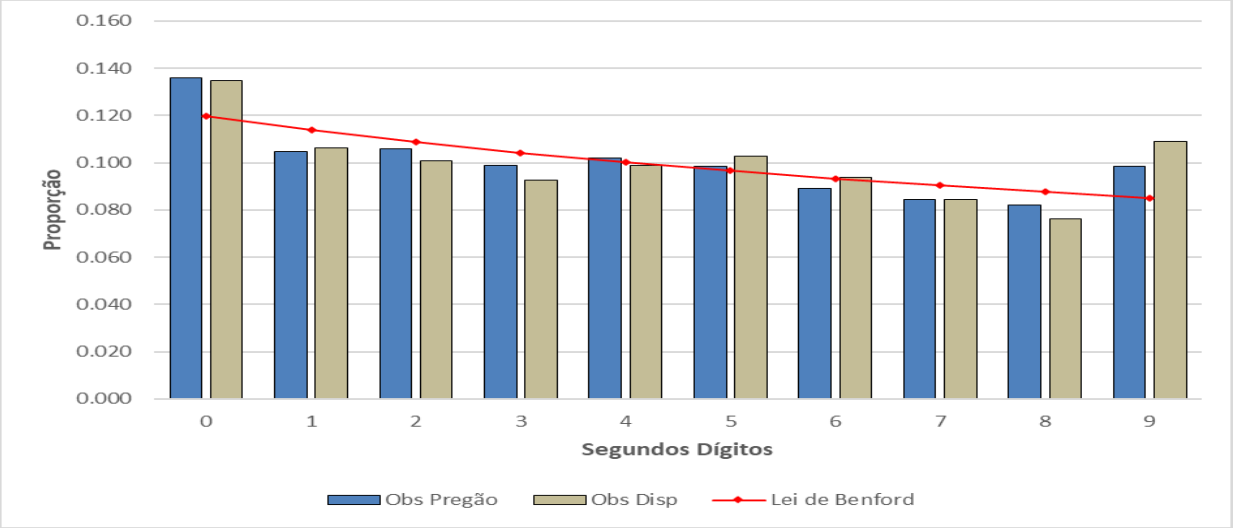


Source: Prepared by the authors.

The visual analysis of the frequencies suggests better conformity of the Auction data compared to the Bidding Waiver, which shows an increase in the proportion of digit 7 and a decrease in digit 3.

In turn, the graphical analysis for the second digits (Figure 6) shows two peaks for digits 0 and 9 in the analyzed modalities, and for digit 5 only in Bidding Waiver. Lower-than-expected frequencies are also observed for digits 1, 2, 3, 7, and 8 in both cases, and for digit 6 only in the Auction.

Figure 6
Proportion of the 2nd digit of direct expenditures in Action 21C0 by bidding modality in 2020



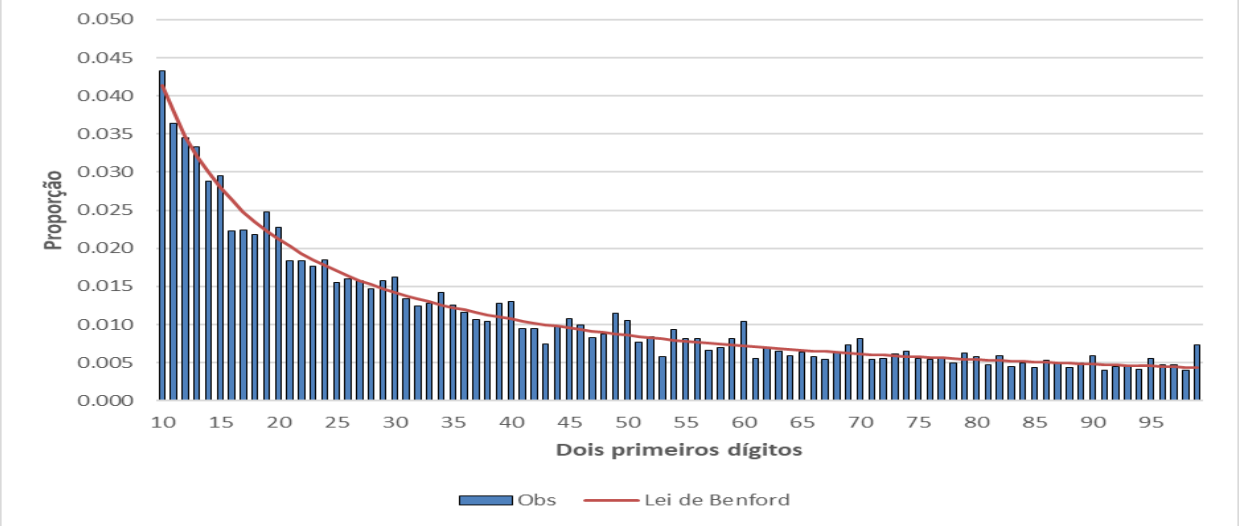
Source: Prepared by the authors.

In the visual analysis of the frequency of the first two digits, Figure 7 shows good adherence to the NBL proportions for the Auction data, with few deviations.

In contrast, Figure 8 shows lower adherence for the Bidding Waiver, with larger deviations, including some peaks, the highest being for digits 26 and 79.

Figure 7

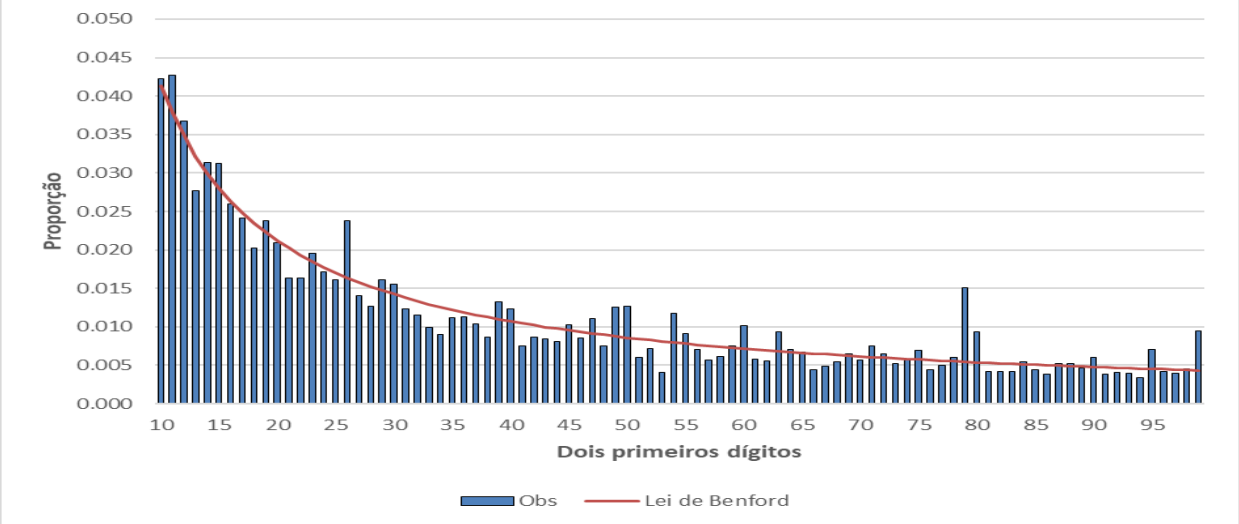
Proportion of the first two digits for the Auction modality in 2020



Source: Prepared by the authors.

Figure 8

Proportion of the first two digits for Bidding Waiver in 2020



Source: Prepared by the authors.

4.4 Conformity of the Data Distribution with the Newcomb-Benford Law

To present the results of the statistical tests and facilitate the discussion with the graphs shown in the previous sections, Table 3 presents the values of the global tests (Chi-Square and MAD) for the first, second, and first two digits. It is important to emphasize that the fact that the tests may indicate non-conformity with the NBL does not allow for conclusions about the existence of manipulation or fraud in public contracts (Varian, 1972; Nigrini, 2012). This merely serves as a warning sign that such discrepancies suggest the need for a more detailed analysis by oversight and control bodies, considering the signals that the approach may present.

Table 3
Results of the tests (Chi-Square and MAD) for the first, second, and first two digits

	Tests	Approach	2020	2021
1st Digit	Chi-Square	Direct Expenditures	29,660	16,081
		Modality		
		Auction Bidding	11,197	-
		Bidding Waiver	49,265	-
	MAD	Direct Expenditures	0,0018	0,0073
		Modality		
		Auction Bidding	0,0021	-
		Dispensa de licitação	0,0045	-
2nd Digit	Chi-Square	Direct Expenditures	323,771	39,169
		Modality		
		Auction Bidding	132,222	-
		Bidding Waiver	181,754	-
	MAD	Direct Expenditures	0,0077	0,0096
		Modality		
		Auction Bidding	0,0067	-
		Bidding Waiver	0,0091	-
First Two Digits	Chi-Square	Direct Expenditures	828,035	198,551
		Modality		
		Auction Bidding	283,356	-
		Bidding Waiver	784,699	-
	MAD	Direct Expenditures	0,0011	0,0023
		Modality		
		Auction Bidding	0,0010	-
		Bidding Waiver	0,0017	-

Source: Prepared by the authors.

Analyzing direct expenditures by year and based on the critical values recommended by Nigrini (2012), the Mean Absolute Deviation indicated adequate conformity of the direct expenditure data in all tests conducted for 2020, while the data for 2021 showed acceptable conformity concerning the 1st and 2nd digits and a lack of conformity for the first two digits. This finding suggests that the year 2021 presents data with lower adherence to the NBL than the year 2020.

A similar conclusion is found in the Chi-Square test, where all results for both years of direct expenditures exceed the critical values, leading to the rejection of the hypothesis of adherence to the expected distribution according to the NBL; that is, the data have lower conformity with the Law. Therefore, the tests again indicate a higher susceptibility to fraud in 2021, which aligns with the observations in Figures 1 to 4.

This finding may be motivated by greater flexibility in the rules and controls of contracting, resulting in an increased sense of impunity in 2021, as the pandemic persisted and there was a "justification" for improper actions based on the public health emergency. It is important to note that 2020 has 37,395 analyzed records, which may have generated a "false positive" bias due to the large sample size, as the test is sensitive to larger samples (Nigrini, 2012).

When comparing the bidding modalities Auction and Bidding Waiver in 2020, concerning the MAD, adequate conformity is observed for the Auction in all tests, while the Bidding Waiver shows adequate conformity only for the first-digit test, with acceptable conformity for the second digits and the first two digits.

For the Chi-Square Test, the statistic values for the Auction modality are lower than those for the Bidding Waiver in all approaches, indicating a poorer fit for the data related to the bidding

waivers. This finding may suggest that the lower level of competition in contracting processes increases non-conformity with the NBL, as found in Ganassin et al. (2016).

4.5 Discussion of Results

The results of the analysis of direct expenditures in Action 21C0 in 2020 and 2021, utilizing the Newcomb-Benford Law (NBL), show variations that align with and, in some cases, diverge from the existing literature on fraud detection in public financial data.

The results indicating greater conformity of the 2020 data with the NBL compared to 2021 corroborate the conclusions of Santos et al. (2005), who identified the effectiveness of the NBL in detecting irregularities in public expenditures. The observed conformity in 2020 can be seen as a reflection of greater adherence to the rules, while the discrepancies in 2021, such as the higher frequency of digit 1 and the lower frequency of digit 2, may suggest possible manipulation, similar to the conclusions of Costa et al. (2012), who observed significant deviations in the distribution of digits in state public expenditures.

The analysis of the results allowed us to infer that, whether from an annual perspective or by bidding modality, digit 9 showed greater non-conformity in 2020. During a period of high demand for health-related products (such as those funded by Action 21C0), the existence of prices above market value is expected (Qin et al., 2021).

Thus, the findings suggest that there are commitments with overpricing, especially in contracts where the first digit is 9. The higher frequency of this digit can be interpreted as a result of price establishment at the upper limit of the value range (for example, in the range of R$ 900.00 or R$ 9,000.00). In a pandemic scenario, it is believed that prices were increased, particularly in bidding waivers that occurred with greater flexibility of rules and controls (Ganassin et al., 2016).

The identification of digit 9 as a point of non-conformity in 2020 aligns with the findings of Ganassin et al. (2016), who also found significant deviations in bidding waivers when applying the NBL, especially in contexts where there was less control and transparency. Similarly, Rodrigues et al. (2023) observed that most municipalities in Paraná did not follow the expected distribution according to the NBL, which could be associated with practices of overpricing or price manipulation, a finding that parallels the results from 2020.

On the other hand, it is important to note that in 2021, the increase in the proportion of digit 1 was accompanied by a reduction in the proportion of digit 2, which would lead to an opposite understanding, that is, a reduction in prices. However, one might hypothesize that there was an increase in the values of the commitment notes from 2020 to 2021, as if the values were rounded up.

Regarding the second digit, both in the annual analysis and by modality, nearly all digits showed non-conformity, with a prevalence of digits 0, 5, and 9. This result indicates signs of price rounding (Nigrini, 2012; Costa et al., 2012), both in 2020 and 2021, with the second year of the pandemic showing this more clearly due to the significant prevalence of digit 0 alone.

In 2021, the higher prevalence of digit 1, contrasting with the reduction of digit 2, may reflect a pattern of rounding values, as pointed out by Silva and Boente (2023), who detected distortions in budgetary and asset expenditures suggesting manipulation or irregular practices, especially during periods of relaxed rules.

Regarding the first two digits, Cunha and Bugarin (2014) suggest that the discussion is more effective when conducted alongside the results of the Sum Test. These results indicate that commitment notes starting with 15 for the year 2020 and with 10 and 15 for 2021 are those that deserve greater attention in potential audits and oversight, as they exhibited greater divergence from the expected result. Similarly, considering only 2020, commitment notes resulting from auctions with values starting at 40 and those contracted by waivers starting at 11 and 26 are more susceptible to value manipulations.

When analyzing the bidding modalities, the greater conformity of the Auction compared to the Bidding Waiver reaffirms the findings of Cella and Zanolla (2018), who identified higher conformity with the NBL in municipalities with greater transparency. This suggests that more competitive and transparent processes tend to align better with the NBL, while the Bidding Waiver, which typically involves less control, shows greater susceptibility to deviations, as also indicated by Ganassin et al. (2016).

The findings of this study reinforce the observations of Da Cruz et al. (2021), who identified probable fraud and manipulation in the expenditures of Brazilian senators, recommending a more detailed analysis of documents that show deviations in conformity with the NBL. Similarly, their study suggests that oversight and control bodies should focus their audits on areas where discrepancies are more evident, such as expenditures with digit 9 in 2020 and digits 1 and 2 in 2021.

In light of the above, there is a greater susceptibility to fraud in contracts occurring in both years, especially in bidding waivers, with the likelihood of fictitious values being included in the commitments or the formation of contracted prices without the appropriate application of markup or other pricing techniques.

In other words, it is believed that, in general, the price formation process did not adhere to good practices in corporate cost management; on the contrary, there are significant chances of price manipulation and the occurrence of fraud during the critical moment experienced in Brazil and worldwide due to the pandemic.

5 CONCLUSION

The present study aimed to analyze the federal government's expenditures in 2020 and 2021 related to combating the pandemic, in search of indicators of fraud. The analysis was conducted from the perspective of the conformity of the commitment note values issued with the Newcomb-Benford Law. Using a methodology based on observing the relative frequencies of the first, second, and first two digits of commitment notes issued during the pandemic, graphs were analyzed and hypothesis tests were performed to verify the statistical significance of the deviations of each digit and the distributions as a whole concerning the NBL.

The research revealed significant indications of irregularities in federal expenditures related to pandemic response in 2020 and 2021. The analysis based on the Newcomb-Benford Law indicated that while the 2020 expenditures demonstrated reasonable conformity with the expected distribution, the 2021 data exhibited greater deviations, suggesting possible manipulation of values. These deviations were particularly evident in contracts made through bidding waivers, which showed greater non-conformity with the NBL compared to contracts made through auctions.

The findings suggest that 2021 was marked by a lower adherence to good compliance practices, possibly due to the relaxation of rules and controls, exacerbated by the continuation of the pandemic. Furthermore, the observed patterns suggest the possibility of overpricing, especially in values starting with digits 9 and 1, which should be prioritized in future audits. In summary, the study confirms the need for stricter oversight of public expenditures during crisis periods, such as those of 2020 and 2021, to mitigate the risk of fraud and ensure the integrity of public resources.

This research offers important contributions for different audiences. For society in general, it highlights the importance of efficient and transparent management of public resources, particularly in crisis contexts such as the COVID-19 pandemic. For researchers in the field of fraud and public resources, the study presents a practical example of the application of the Newcomb-Benford Law in detecting anomalies in financial data, paving the way for the development of more robust and effective methodologies to combat fraud in the public sector. Auditors may find an

additional tool to enhance their oversight practices, allowing for more accurate identification of potential irregularities in public contracts. Finally, professionals can use these findings to develop strategies that prevent manipulations and ensure the integrity of accounting and financial records, thereby contributing to a more trustworthy and compliant environment in public finances.

As limitations of the research, it is noteworthy that public expenditures related to the pandemic extend beyond those linked to budget action 21C0 and continue after 2020 and 2021. Additionally, in 2021, the number of commitment notes was considered insufficient for comparing the adherence of contracts through auctions and bidding waivers, limiting the study's results. Despite these limitations, this study can be useful for professionals working in government auditing, oversight and control bodies, as well as public security entities. By encouraging a thorough sample selection in audit work, especially regarding pandemic-related expenditures, this research has the potential to promote resource savings for public entities through more effective analyses, which can lead to a medium- and long-term educational effect beneficial to society.

Finally, the techniques discussed may encourage new research, especially in the field of public management, generating knowledge accumulation and procedural renewal. Future research on the topic could include data from 2019, prior to the onset of the pandemic, to assess the influence of the emergency situation on the conformity of federal expenditures, as well as data from 2022, a year in which expenditures likely represented the "normal" scenario, with the gradual return of economic activities and the repeal of "flexibilizing" laws on contracts.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding this submitted work.

AUTHOR CONTRIBUTIONS

Roles	1ª author	2º author	3º author
Conceptualization	♦	♦	
Data Curation	♦		
Formal Analysis	♦	♦	
Funding Acquisition			
Investigation	♦	♦	♦
Methodology	♦	♦	♦
Project Administration		♦	
Resources	♦		
Software	♦		
Supervision		♦	♦
Validation	♦	♦	♦
Visualization	♦	♦	♦
Writing – Original Draft	♦	♦	♦
Writing – Review and Editing			♦