

ARTICLES

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PUBLIC PROCUREMENT IN BRAZIL: EVIDENCE OF FRAUDS USING THE NEWCOMB-BENFORD LAW

Compras públicas en Brasil: indicaciones de fraudes utilizando la Ley de Newcomb-Benford

Compras públicas no Brasil: indícios de fraudes usando a lei de Newcomb-Benford

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ABSTRACT

This article uses the Newcomb-Benford(NB-Law), or Law of Anomalous Numbers, to analyze the values of Electronic Bidding Processes that occurred in the Purchasing Portal of the Brazilian Federal Government and contained in the newly created website “DadosAbertos.gov.br”. In the analysis, all services contracted in the period from 2014 to 2018 were considered. The objective of the research was to analyze the conformity of the Electronic Auction referred to the NB-Law, aiming to verify anomalies, which represent signs of fraud. It can be said that there was a statistically significant anomaly in the analysis of the first digit of the values bid in the Electronic Bidding Tenders. It is also noted that the trading sessions with the first digit of numbers 4, 8 and 9 are those with the largest differences between expected and observed values, strengthening the hypothesis that these represent the trading sessions with the highest incidence / probability of deviations, to be tested in future studies. The study, pioneer in this type of analysis in the Brazilian data source, aims to contribute to the literature focused on the detection of accounting or financial fraud in the public sector. The results collected here can also contribute to the practice of inspection in public management. It is recommended to deepen the studies based on the Economics of Corruption, on issues that involve the detection of fraud, so that corruption becomes unviable or inopportune.

Keywords: public procurement, electronic auction, corruption, Newcomb-Benford law, bidding frauds.

RESUMEN

Este artículo utiliza la Ley de Newcomb-Benford (Ley-NB), o Ley de Números Anómalos, para el análisis de los valores de las Sesiones de Comercio Electrónico realizadas en el Portal de Compras del Gobierno Federal de Brasil y contenidas en el sitio web recién creado “DadosAbertos.gov.br”. En los análisis, fueron considerados todos los contratos de servicios, de 2014 a 2018. El objetivo de la investigación fue analizar el cumplimiento de las Sesiones de Comercio Electrónico mencionadas a la Ley-NB, con el fin de verificar anomalías que representen evidencia de fraude. Se puede afirmar que hubo una anomalía estadísticamente significativa en el análisis del primer dígito de los valores licitados en las ofertas de las Subastas Electrónicas. También se observa que las sesiones de trading con el primer dígito de los números 4, 8 y 9 son las que presentaron los valores intermedios más altos que contribuyen al chi-cuadrado χ^2 calculado, fortaleciendo la hipótesis de que estas representan las sesiones de trading con la mayor incidencia/probabilidad de desviaciones. El estudio, pionero en este tipo de análisis en la base de datos brasileña, tiene como objetivo contribuir a la literatura centrada en la detección de fraudes contables o financieros en el sector público. Los resultados aquí recogidos también pueden contribuir a la práctica de la supervisión en la gestión pública. Se recomienda profundizar en el análisis de las ofertas estudiadas, con el fin de confirmar las evidencias aquí recogidas, y centrarse en estudios basados en la Economía de la Corrupción en cuestiones relacionadas con la detección de fraude, de modo que la corrupción se vuelva inviable o impropia. **Palabras Clave:** contratación pública, negociación electrónica, corrupción, ley Newcomb-Benford, fraude en licitaciones.

RESUMO

Este artigo utiliza a Lei de Newcomb-Benford (Lei-NB), ou Lei dos Números Anômalos, para análise empírica exploratória dos valores de pregões eletrônicos ocorridos no Portal de Compras do Governo Federal brasileiro e constantes no recém-criado site “DadosAbertos.gov.br”. Nas análises foram consideradas todas as contratações de serviços no período de 2014 a 2018. O objetivo da pesquisa foi analisar a conformidade dos pregões eletrônicos mencionados à Lei-NB, visando a verificar anomalias que representam indícios de fraude. Pode-se afirmar que há anomalia estatisticamente significativa na análise do primeiro dígito dos valores licitados nos pregões eletrônicos das licitações. Constata-se também que os pregões com primeiro dígito de números 4, 8 e 9 são os que apresentaram maiores diferenças entre o valor observado e o valor esperado, fortalecendo a hipótese de que esses representam os pregões com maior incidência/probabilidade de desvios. O estudo, pioneiro nesse tipo de análise na base de dados brasileira, visa a contribuir para a literatura focada na detecção de fraudes contábeis ou financeiras no setor público. Os resultados da pesquisa indicam que podem contribuir, também, para a prática da fiscalização na gestão pública. É recomendado aprofundar a análise das licitações estudadas, visando a confirmar os indícios constatados, e focar em estudos baseados na economia da corrupção nas questões que envolvem a detecção de fraudes, a fim de que a corrupção se torne inviável ou inoportuna. **Palavras-Chave:** compras públicas, pregão eletrônico, corrupção, lei de Newcomb-Benford, fraude em licitações.

INTRODUCTION

Sacramento and Pinho (2018) agree that the dominant perception in Brazil about corruption is that this phenomenon has assumed a systemic character. Such understanding would be a consequence of the daily exposure of scandals involving both the powers of the state and private organizations, in all spheres of government.

According to Rose-Ackerman (1997), the problem of corruption arises from the difference in the utility function of the principal and the agent. While the government seeks the social optimum, the agent seeks the private optimum, which, most likely, diverges. Systemic corruption undermines the legitimacy of governments, especially in democracies, and can even lead to coups by undemocratic leaders. Conversely, non-democratic governments can use corruption to maintain power by spreading its benefits. If the richest and most powerful individuals are part of a network of corrupt gains and favors, the threat of exposure can help the current rulers maintain power. Thus, corruption need not be destabilizing, but it always runs counter to the norms of open and fair dealing (Rose-Ackerman, 1997).

In competitive contexts, procurement is commonly designed to select the most efficient supplier in a group of competing firms and maximize the buyer's savings (Albano, Buccirosi, Spagnolo & Zanza, 2006). Firms, however, do not like to compete (O'Farrell, Hitchens & Moffat, 1992), and possibly would prefer to coordinate their actions in order to soften price competition and increase joint profit. Such coordination, whether explicit or tacit, is both tempting and feasible, since most acquisitions are repeated over time. The goal of most companies is to maximize profits. Their behavior is affected by the rules and regulations that the public sector imposes on the private sector and the monitoring by the public sector to ensure compliance with its regulations (Navot & Cohen, 2015).

In 2016, the federal government spent R\$49 billion in goods, i.e., materials and equipment, and R\$40 billion in contracting services. (Empresa Brasil de Comunicação, 2017). According to the Organization for Economic Co-operation and Development [OECD] (2008), electronic procurement plays an important role in minimizing the risk of corruption in these public contracts. The recent fight against corruption has been established by the European Union as one of the main objectives of modern public procurement regulation and policy. (Miranzo Diaz, 2017).

The electronic auction replaces other bidding methods, such as the Bidding, Invitation for Bids, and Invitation Letter. The system already works in several states, with great advantages for participants, whether they are state agencies, entrepreneurs or observers. For this reason, the electronic form of the bidding system is the focus of this study.

Brazil is in the 96th position in the 2017 Transparency International corruption perception ranking, and in the previous year it occupied the 79th position (Transparency International, 2018). According to Campos (2012, p.34), the corruption perception survey originated in agencies specialized in analyzing investment risks. Based on the surveys of these institutions, the anti-corruption organization Transparency International created the Corruption Perceptions Index, which ranks the countries of the world according to the degree of corruption perceived by

respondents, who range from executives of large companies, high-ranking civil servants, jurists, professors and even journalists.

Despite the apparent advantages obtained with the implementation of electronic bidding in public tenders, some irregularities, such as the use of robots to bid, overbilling and prior combination of bidders, may still be occurring. According to Contas Abertas (2017), the evolution in the number of injunctions adopted by the Federal Audit Court involving the suspension of bids shows the fragility of the technology most used by the federal government – the electronic auction. In this sense, this study is relevant because it was designed to verify the integrity of the disputes and broaden the debate for a possible scientific-based improvement.

The objective of the research is to analyze the bids compliance with NB-Law in electronic auctions and identify anomalies such as indications of fraud. The results show which groups of bids do not comply with the said law, indicating probability of fraud, as observed by Costa, Santos and Travassos (2012). We aimed, therefore, to answer the following question:

How does the NB-Law enable detection of frauds in bids in the Brazilian Public Procurement System?

The study, pioneer in the use of the NB-Law in the Brazilian public procurement sector, is relevant in the sense that its results can contribute to the accumulation of empirical and theoretical knowledge, expanding safer bases for action by governments and society to combat corruption and, consequently, promote greater effectiveness and efficiency of public spending. We hope to contribute to the literature focused on detecting accounting or financial fraud in the public sector and inspection in public management.

This study is divided into five sections: after this introduction, the literature review and the theoretical framework are presented. Next, comes the hypothesis of the study, then data collection and research methods. The next section presents results and discussion, and, finally, the conclusion with practical implications and limitations.

LITERATURE REVIEW

This section presents and discusses theories, arguments and controversies and highlights research already conducted, identifying gaps and choosing theoretical and methodological strategies to reduce them and broaden the knowledge of the research object (Gray, 2012). To this end, the literature review is divided into three topics: Economics of Corruption, which is the theoretical framework of the research, Fraud in Public Bids made through electronic auctions, and, finally, the NB-Law, the research problem and its hypotheses.

The Economics of Corruption

Corruption is defined as all types of behavior in which a person in a position of trust misuses that power for his or her own benefit. In its procurement guidelines, the World Bank defines a “corrupt practice” as “Offering, giving, receiving or soliciting, directly or indirectly, anything of value to influence the action of a public official in the procurement or contract process” (Lengwiler & Wolfstetter, 2006, p. 412).

The Economics of Corruption had its origins with the works of Becker (1968) and Rose-Ackerman (1975). For Becker (1968), individuals and the State optimize their utility functions, including illicit actions, by evaluating the cost/benefit ratio of their actions, finding an “optimal point” of illegal practice – the individual evaluates the expected gain as a benefit and the expected penalty as a cost, while the State evaluates society’s welfare (security) as a benefit and the expenditure on public security, justice, and imprisonment as a cost. Following this line of reasoning, Rose-Ackerman (1975) analyzes corruption with a focus on the Principal-Agent model. In the model, the principal (government) delegates tasks to its employees (agents), who perform them subject to bribery proposals from those affected by the task. Also according to Rose-Ackerman (1997), if the probability of detection and punishment is high, bribes may not be worth it.

According to Søreide (2002), the main reason for bribery in public procurement is probably because everyone believes that everyone else is involved in such business. Losing a contract because a competitor has bribed someone must be very frustrating. This problem of hidden information is reflected in the way all companies involved pay bribe, even if they would be better off without corruption (prisoner’s dilemma). Thus, firms that bribe authorities seem oblivious to the negative externality they impose on other firms and to the worsening of their economic environment. According to Miranzo Diaz (2017), the approach to the problem of corruption, which establishes the need for strategic decisions, the practical implementation of integrity principles and their related concepts, justifies the appropriateness of promoting the implementation of anti-corruption measures. In this sense, increasing the mechanisms for detecting fraud and anticompetitive practices in electronic procurement is in line with the aforementioned theory.

According to Tóth and Hadju (2017), current studies address corruption risks and their integrity mechanisms, which should be complemented, for example, with integrity indicators of contracting entities. If these integrity efforts exist, there is a compliance activity, that is, policies, guidelines and standards established for the business and activities of the institution or company. Since basic data on public procurement are available, they can be analyzed at any level of aggregation (e.g., groups of firms, municipalities, administrative units, operational programs). Thus, there is theoretical support to propose improvements in the monitoring system of electronic auctions.

Fraud in Public Procurement conducted through electronic auctions

Corruption necessarily involves a public agent, whose entrusted power is used for private gain (Transparency International, 2018). Fraud, on the other hand, is characterized when public or private agents act to obtain illicit advantages, conceal their decisions and their respective effects. Fraud and corruption, although similar in ethical violation, are different events (Jamal, Johnson & Berryman, 1995).

Fraud is the intentional action promoted for one's own benefit by an agent to the detriment of others, enforcing the law of least effort. Iudícibus, Marion, Pereira and Slomski, (2001, p. 96) define fraud in accounting as the act of cheating for one's own benefit, which can be characterized as theft, embezzlement, stalion, falsification. Costa and Jr. (2012, p. 465) conceptualize fraud as a set of illicit actions performed in a premeditated way by the authors, which aim to meet their own interests but cause losses to the assets of others.

According to Hanák (2018), when certain principles and limitations are respected, the electronic auction can be successfully used for the acquisition of goods, services, and works. In Brazil, electronic auctions are not yet allowed for works. Also according to the results of Hanák's (2018) survey, the users of electronic auction perceive the effects of Bid differently, especially regarding price and quality. Non-user buyers assume that electronic auctions have a positive impact on the transparency of the process and also believe that financial savings can be achieved through electronic auctions. However, the suppliers interviewed are concerned about the decrease in the number of competitors and quality.

Government authorities have increasingly used the Internet for public procurement processes. The main objective here would be "the quality of public spending," promoting access, competition, fairness and transparency, and allowing control by civil society. The electronic auction is synonymous with an instrument of efficiency in public procurement and contracting, whose economy and celerity are its main hallmarks, but the system is not free from fraud (Lima, 2016).

According to the Federal Court of Accounts [TCU] (2018), the risk of fraud and corruption is reduced if the organization knows well the third parties it is dealing with, especially in the most significant purchases, where the risk of receiving kickbacks and secret commissions is high.

According to Albano et al. (2006), the emergence of "bidding cartels" in procurement, i.e., collusive arrangements in bidding processes, is driven by forces very similar to those governing the formation of cartels in oligopolistic markets, seen as an association of firms aiming to predefine the winner.

The electronic auction was created with the intention of facilitating bids and guaranteeing greater competition, allowing all interested parties to participate without having to travel to the site of the competition. As already mentioned, the first major controversy regarding the electronic auction is the use of software by bidders, because some of them have artificial intelligence and are called robots, which, although not prohibited by law, can be interpreted as an anti-competitive practice. These robots are used to detect some kind of bid and immediately cover the bid, usually with pennies difference. Since the end of the bidding phase is random, the winner is determined by chance (Campana, 2018).

According to Lengwiler and Wolfstetter (2006), auctions are an efficient mechanism for contracting. That is why they have been used for centuries in the classical form, as auctions, and are being used more frequently. But they are not immune to manipulation through collusion and corruption. The authors explain that "collusion means that bidders coordinate

their actions with the intention to increase the price. Corruption means that the person who runs the auction, the auctioneer, twists the auction rules in favor of some bidder(s) in exchange for bribes.” (Lengwiler & Wolfstetter, 2006, p. 412). Thus, corruption and collusion are sometimes intertwined.

According to Rebouças, Prado, Ferneda, and Balaniuk (2017), in Brazil, the electronic auction on the Comprasnet system fosters deals in the order of millions of reais every year, and companies supplying services and products may be using this medium as an opportunity to carry out transactions aiming at higher profits, sometimes illicitly.

In a more recent work, the TCU (2018) mapped the risk of exposure to fraud and corruption in the Federal Public Administration, in Brazil, using a scale of “Economic Power” in association with an Index of Fragility of Fraud and Corruption Controls. The court concluded that there is a strong link between the incidence of fraud and corruption, and weak preventive controls, and that in many cases where fraud and corruption are detected, it is possible that there were failures in preventive controls that allowed the incident to occur, and that preventive controls work by deterring the commission of fraud and corruption. These preventive controls include a good governance system, fraud and corruption risk management, anti-fraud/anti-corruption training, and technological devices for monitoring and detecting evidence of these practices.

According to Bajari, Mc Millan and Tadelis (2009), bidding is understood to select the lowest cost bidder, avoid corruption and favoritism, yet oppose efficiency, and also provide a clear benchmark with which to compare bids.

In counterpoint, Campana (2018), points out that the idea of electronic auction is extremely advantageous for the Public Administration, as it ensures greater competition to the contest, since it allows greater amount of bidders due to its online access.

In this sense, it is no surprise that many governments, whether state, municipal or foreign, have invested more and more to equip their procurement structures with professionals and means capable of using the electronic auction to ensure transparency, effectiveness and speed in public procurement.

Fraud or any facilities for combining proposals or directing the competition cannot be attributed to the electronic auction, because, on the contrary, of all the available modalities, the electronic Bid, as a rule, is the best option to meet the three bidding objectives set forth in Article 3 of Law No. 8,666/1993: “compliance with the constitutional principle of isonomy, selection of the most advantageous proposal for the administration and promotion of sustainable national development.” (Barcelos, 2018)

One of the methods used to verify evidence of fraud or anomalies in data of various types, is the NB-Law, to be discussed below.

The NB-Law

The NB-Law was developed by Newcomb (1881) and Benford (1938), authors who proved that the probabilities of occurrence of values initiated by lower digits are higher than the probabilities of occurrence of values initiated by higher digits. This Law proposes that the frequencies of

the first digits in a multitude of databases are decreasing from 1 to 9; the number 1 appears in approximately 30% of the data, while 9 does not reach 5% of these values. This is exemplified in Table 1.

Table 1 – Frequencies of the first digits of values, according to NB-Law

First digit	1	2	3	4	5	6	7	8	9	Total
Percentage (%)	30.00	17.67	13.00	9.00	8.33	6.33	5.67	5.67	4.33	100.00

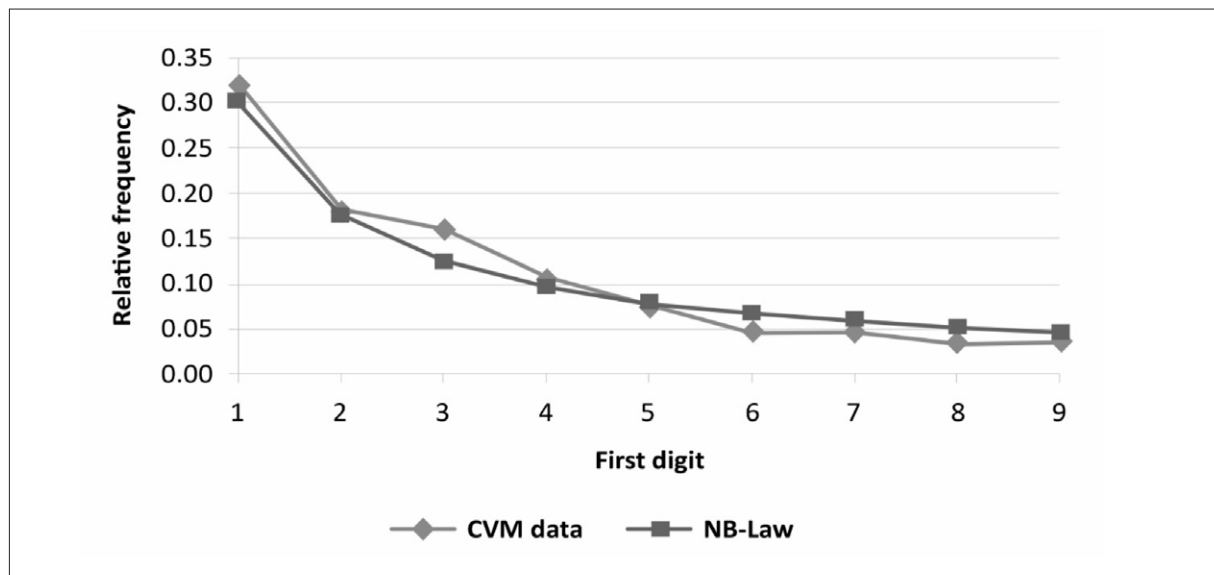
Source: Adapted from Kira and Teixeira (2016, p. 1).

The axiom of deducing the probabilities of occurrence of numbers 1 to 9 in the first significant digits was first obtained by Benford (1938) and was widely used and refined by Hill (1995a,1995b). The probability $P(d)$ of the number d occurring as the first significant digit is obtained by the equation:

$$P(d) = \log_{10} \left(1 + \frac{1}{d} \right) \quad (1)$$

This same application can be valid for prices, for example, the values (in Reais) of 1,274 invoices from the Securities and Exchange Commission, shown in Graph 1:

Graph 1 – Frequency of the first digits in invoices from the Securities and Exchange Commission



Source: Kira and Teixeira (2016, p. 1).

Authors such as Hill (1995a, 1995b), Pinkham (1961) and Raimi (1969) have shown that the NB-Law applies to numerical data that are invariant as to scale and random in nature. In this sense, financial flow data have received considerable attention in the literature as amenable to applications using this law. Exhibit 1 summarizes the use of the NB-Law by several authors from different fields of Science, in order to strengthen the justification for using the method in this study.

Exhibit 1 – Summary of the use of NB-Law by various authors

AUTHOR/ YEAR	TITLE OF WORK	AREA	CONTRIBUTIONS
Newcomb 1881	Note on the frequency of use of the different digits in natural numbers	Astronomy	First observations regarding this phenomenon.
Benford 1938	The law of anomalous numbers	Physics	The phenomenon has been rediscovered.
Pinkham 1961	On the distribution of first significant digits	Statistics	They showed that the NB-Law applies to data of a numerical nature.
Raimi 1969	The peculiar distribution of first significant digits		
Varian 1972	Benford's Law	Social Sciences	He concluded favorably on the use of the NB-Law to aid in the detection of financial irregularities.
Carslaw 1988	Anomalies in income numbers: evidence of goal oriented behavior	Finance	He analyzed financial statements of 220 New Zealand companies.
Thomas 1989	Unusual patterns in reported earnings	Finance	He studied patterns of the NB-Law in profit information of US companies.
Hill 1995a 1995b	Base-invariance implies Benford's law	Statistics	It proved mathematically that the NB-Law applies to data of a numerical nature that have invariance as to scale and are random in nature.
	A Statistical derivation of the significant-digital law		
Nigrini 1996 1999	Taxpayer compliance application of Benford's law	Audit	He observed that the NB-Law can be used to detect evidence of human manipulation of data/ He showed that the NB-Law could be used in accounting and forensic auditing as an indicator of fraud.
	I've got your number		

Vellez 2011	Auctions versus Negotiations: Evidence from Public Procurement in the Italian Healthcare Sector	Procurement in Public Health	She performed a NB-Law-based test to rule out collusion among participants in procurement processes.
Costa et al. 2012	Conformity analysis in public spending of federal entities: a case study of an application of the Newcomb-Benford Law for the first and second digits in two Brazilian states	Public Management	They found significant deviations in the 1st and 2nd digit distribution of the analyzed states.
Cunha and Bugarin 2014 2017	Benford's Law and auditing public works: an overpricing analysis of the Maracanã stadium renovation Benford's Law applied to the audit of the reform of Minas Gerais International Airport	Public Management	They did an overpricing analysis on public works.
Kira and Teixeira 2016	Benford's Law and applications	Math	They intuitively summarized what is known as the "NB-Law" for the probability distribution of the first digit of numbers in a data set.
Tóth and Hadju 2017	Intensity of Competition, Corruption Risks and Price Distortion in the Hungarian Public Procurement – 2009–2016	Public Management	They analyzed corruption in the Hungarian government's receipt of funds and procurement.

As shown in Exhibit 1, the earliest mapped work that applied the NB-Law to aid in the detection of financial irregularities was by Varian (1972). Two studies by Nigrini (1996, 1999) highlight possibilities of using the same Law in accounting, auditing, and forensic areas. More recently, studies conducted by Vellez (2011), Costa et al. (2012), Cunha and Bugarin (2014), Kira and Teixeira (2016), Bugarin and Cunha (2017) and Tóth and Hajdu (2017) consolidate the use of the NB-Law in studies on the approach of the economics of corruption.

There is a vast literature focused specifically on the analysis of financial and accounting figures, which indicates that non-compliance with the NB-Law is linked to fraud. Lu et al. (2006) showed that NB-Law can be used even with incomplete data sets to identify fraudulent transactions. They combined this law with reinforcement learning and created a fraud detection approach. Fraudulent transactions were detected by calculating the deviations from the expected distributions of the NB-Law. According to the authors, any anomaly indicates high probability of fraudulent transaction. Similarly, Tóth and Hadju (2017) used NB-Law to check public procurement in Hungary and argue that the law points to evidence of corruption in the receipt

of funds and procurement. Cunha and Bugarin (2014; 2017) state that statistically significant deviations from the NB-Law raise suspicion of financial fraud. Costa et al. (2012) propose that the occurrence of deviations in the behavior of digits indicates the possibility of errors and fraud practiced repeatedly. Berton (1995) studied financial fraud detection, also using NB-Law. Bhattacharya (2002) indicated how this law can assist auditors in tracing the perpetrators of financial fraud. Das and Zhang (2002), likewise Carslaw (1988) and Caneghem (2002), studied the manipulation of stock earnings (profits) by firms, concluding that there was evidence of presence of upward rounding in transactions that increased firms' profits and performance. The aforementioned author Nigrini, in several studies (Nigrini, 1996; 1999; 2005) points out that significant deviations from the R are linked to intentional data alteration, i.e., frauds by increasing financial values.

It is clear, therefore, that significant deviations from the R can be seen as strong evidence of presence of fraud. Several types of fraud are possible in the e-bidding environment, which were discussed in the previous subsection.

Given the discussion previously held, which addressed potential advantages and weaknesses of electronic auctions held in Brazil, and the presentation of one of the methods used to check for evidence of fraud or anomalies in data of various types, the following hypothesis is raised:

H1: The first digit of the values of services bid in the Brazilian public sector through electronic procurement conducted between 2014 and 2018 deviates from the natural distribution of digits expressed by the NB-Law.

DATA COLLECTION AND RESEARCH METHOD

The methodology used in this research consisted of conducting exploratory empirical analysis based on the use of NB-Law in a dataset. The research used data contained in the Purchasing Portal of the Federal Government and in the recently created "DadosAbertos.gov.br." First, a database was built with information on the winners of the bids and their contracted values, extracted from the Purchasing Portal of the Federal Government and from the website "DadosAbertos.gov.br." The bid amount in the period is around R\$260 billion, encompassing all types of bidding, which resulted in 557,567 procurement processes. The data filtered by period, type of bidding, and form of bidding, reach the amount of more than R\$120 billion only in acquisitions through electronic auctions, of which 111,068 auctions were held. As the focus of the research are the auctions for hiring services – because these generally have only one winning bidder per auction –, this filter was performed, resulting in a universe of 41,898 auctions, in the bidding modality, electronic auction and hiring services, being disregarded 4,713 auctions with values of zero or below R\$ 1.00 (one real), resulting in 37,184 auctions to be submitted for analysis.

The evaluation was performed with a focus on the distribution of the first significant digit (non-zero) and an assessment was made of the relative frequencies of numbers 1 to 9, observed in the first position in the set of selected electronic trading floor values, these being the variables of analysis, also used by Carslaw (1988), Nigrini (1996), Costa et al. (2012), Cunha and Bugarin (2014) and Kira and Teixeira (2016). In the analyses all services contracting in a five-year interval, 2014 to 2018, were considered. Then the adherence of the data to the NB-Law was checked, to identify deviations.

To justify the period used, in January 2014 the Anti-Corruption Law is implemented in Brazil, and 2018 is the year immediately before the beginning of the research. The Special Contracting Regime (RDC – *Regime Diferenciado de Contratação*) was not included here, which, although it consists of electronic bidding, has specificities and regulations different from those of public tenders. In this sense, only reverse auctions for hiring services will be analyzed, since there is generally only one winning bidder per auction, making it possible to associate the winning bidder with the variables to be analyzed, and also because they are the means for a type of contracting in which there is a certain degree of difficulty in finding similar market price parameters. This is because the bidding for services has specificities and diversities, reflected in variables such as location, execution deadline, period of execution, etc. Therefore, the procurement of services facilitates the subsequent association between the bid, its value and the winning bidder, besides being a type of contract with greater variation in market prices, making this filter or stratum more interesting to analyze.

The Federal Government's Purchasing Portal was chosen due to its greater comprehensiveness and use of open data.

According to the premise also used by Diniz et al. (2010), the significant deviations signaled by the analysis of the following results indicate human interference with the natural behavior of the numbers in the first significant digit of the values of the electronic biddings evaluated, and this interference, in turn, indicates the occurrence of fraud. The validation was done by the c^2 test of adherence (at 5% significance level). Software Microsoft Excel and statistical package Stata 15 were used.

RESULTS AND DISCUSSION

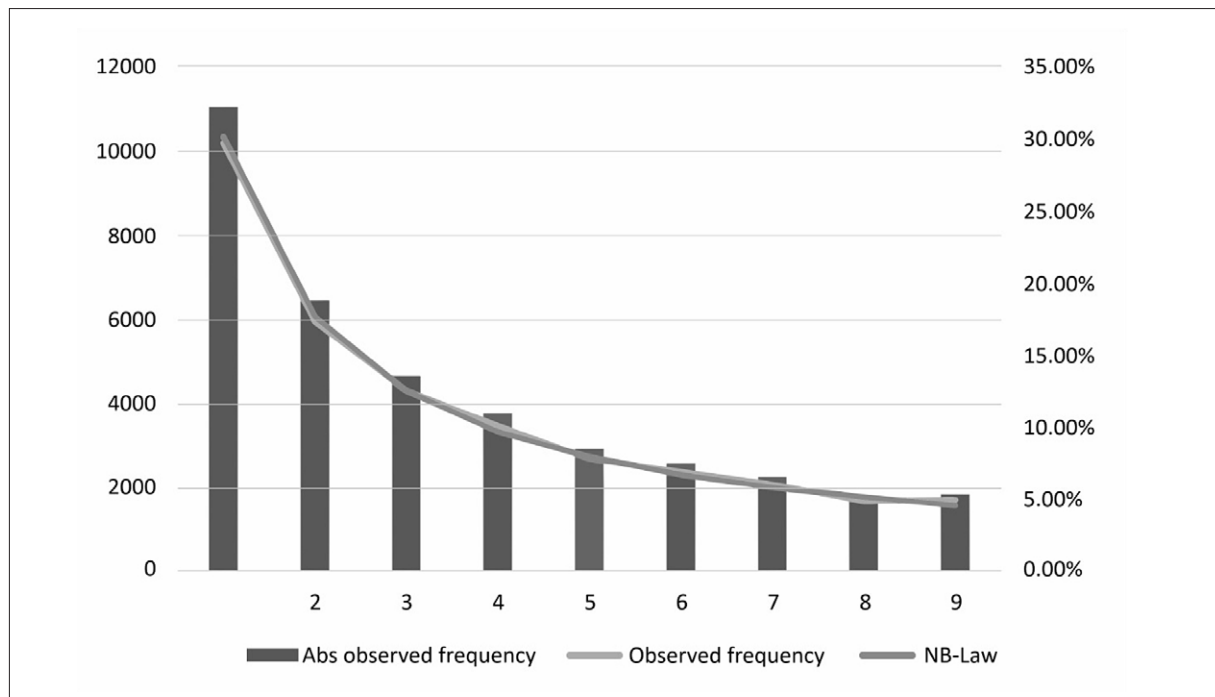
The absolute and percentage frequencies of the values in the initial digit of the bids, obtained by the dynamic table resource, are shown in Table 2.

Table 2 – Frequency of values in the initial digit of the bid value and comparison with expected values

INITIAL VALUE (NUMBER)	OBSERVED ABS. FREQUENCY	OBSERVED FREQUENCY	NB-LAW
1	11039	29.69%	30.10%
2	6435	17.31%	17.61%
3	4645	12.49%	12.49%
4	3748	10.08%	9.69%
5	2905	7.81%	7.92%
6	2563	6.89%	6.69%
7	2232	6.00%	5.80%
8	1794	4.82%	5.12%
9	1823	4.90%	4.58%

The results found and shown in Graph 2 represent the adherence of electronic procurement conducted between 2014-2018 to NB-Law.

Graph 2 – Adherence of electronic procurement conducted between 2014-2018 to NB-Law



From this initial verification, presented in Graph 2, even if visually, it is possible to notice the existence of deviating points between the lines that represent the frequencies of the first digits observed and the natural numbers of the NB-Law; however, visualization alone does not provide robustness to the analysis. Therefore, as described in the studies by Carslaw (1988), Nigrini (1996), Costa, Santos, and Travassos (2012), Cunha and Bugarin (2014), Kira and Teixeira (2016), and Sartori Cella (2018), the validation of the observed degrees of dispersion by the χ^2 test of adherence statistics was required to verify the significance of the deviations in relation to the NB-Law, as recommended by Saffi (2003), Lima and Issler (2003), and Souza (2017).

To perform the χ^2 test, the following formula was used:

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

In this analysis, k is each category (in this case, each of the 9 possible values of the first digit), CO is the observed count of numbers belonging to each category, and CE is the count expected by the NB-Law for the category. The critical value of the statistic χ^2 for 5% significance and 8 degrees of freedom is 15.51. If the resulting statistic is less than the tabulated limit, conformity with the Newcomb-Benford distribution is confirmed. Otherwise, the data set does not conform.

Table 3 – Statistical Tests of the Application of the NB-Law to the Data

INITIAL DIGIT	ABSOLUTE OBS. FREQUENCY	ABSOLUTE EXPECTED FREQUENCY (NB)	(OBS. - EXPECTED FREQ.)	(OBS. - EXPECTED FREQ) ² /EXPEC.FREQ
1	11039	11193	-154	2.13249236
2	6435	6548	-113	1.942450998
3	4645	4646	-1	0.000112202
4	3748	3604	144	5.794278593
5	2905	2944	-39	0.523918783
6	2563	2489	74	2.179046079
7	2232	2156	76	2.652375725
8	1794	1902	-108	6.138605822
9	1823	1701	122	8.683932206
Statistical Test(χ^2)				30.04721
p-value				0.02074%

In Table 3, the value of χ^2 , 30.04721, was higher than the critical value, with a corresponding p-value of 0.02074%, indicating that the frequency of observed data is different from the frequency of expected data.

Thus, Hypothesis H1, that the first digit of the values of services bid in the public sector through electronic auctions in the population deviates from the natural distribution of digits expressed by the NB-Law was not refuted, that is, it has its confirmation from the results of the empirical analysis, in light of the theory and referenced authors. Therefore, we can state that there is evidence of significant anomaly in the numbers of the first digit, indicating the probability of fraud in electronic bidding in the evaluated population, fulfilling the objective of this study. And yet, according to the result highlighted in Table 3, the auctions with values 4, 8 and 9 in the first digit are the ones with the highest intermediate values that contributed to the calculated c^2 , generating the hypothesis that these are the auctions with higher incidence/likelihood of deviations. The results show that there is evidence of fraud in the evaluated auctions, which is in line with the method and conclusions of similar studies already cited, such as those of Toth and Hadju (2017), Cunha and Bugarin (2014; 2017), Costa et al. (2012), Berton (1995), Bhattacharya (2002), Das and Zhang (2002), Carslaw (1988), Caneghem (2002) and Nigrini (2005; 1996; 1999).

In the population, there were bids of small values, between R\$1.00 and R\$10.00, positioned below the minimum threshold for applying the Z-test (Nigrini, 1996), a test that could confer even greater robustness to the analysis. Such small values could not be disregarded because they represent services in which the unit values are small but the volume of use is large, as in the case of outsourcing printing services.

As pointed out in the literature review, the main existing forms of anticompetitive practices or corruption in electronic bidding include the use of computer programs that send bids automatically, the fixing of prices among bidders, the use of companies formed to frustrate competition in disputes and favor certain bidders, and the association between public agents and suppliers in order to circumvent the legal procedure (Albano et al. (2006); Lengwiler and Wolfstetter (2006); Hanák (2018); Lima (2016), TCU (2018); Campana, 2018). The statistical analysis performed here does not allow us to characterize or classify the incidence of each of these forms of corruption, but the indication that they exist is a motivating factor for the development of mechanisms to prevent them or make them disadvantageous. Such mechanisms could be precisely those that prevent the use of robots by bidding companies (Campana, 2018), or that frustrate the simulation of real bids or detect the combination of bidders by analyzing the behavior of companies throughout a sequence of bids.

CONCLUSIONS AND IMPLICATIONS

In line with the government's objectives of favoring electronic public procurement processes, such as electronic auctions, and in pursuit of the goal of increasing "the quality of public spending," promoting access, competition, impartiality and transparency and allowing control by civil society, this study collected evidence regarding the integrity of bids held electronically in the Brazilian Public Procurement System. We analyzed the conformity of the bids with the Brazilian NB-Law in the environment of the electronic auctions analyzed, as a strategy to identify anomalies representing evidence of fraud. The database of

electronic procurement tenders for contracting services, conducted via the Brazilian Federal Government Purchasing Portal, between 2014 and 2018, was used. This is a pioneering effort in the use of the NB-Law for this purpose in the sphere of public procurement in an electronic environment in Brazil.

This study can contribute to the accumulation of empirical and theoretical knowledge, expanding safer bases for governments and society to combat corruption and, consequently, to greater effectiveness and efficiency of public spending.

As evidenced, there is a vast literature indicating that non-compliance with the NB-Law is linked to fraud in financial and accounting values, although not in the environment that is the focus of this study. This research is complementary to those studies and aims to contribute to that branch of literature. The results may also indicate the practice of oversight in public management.

By pointing out evidence of irregularities, the results emphasize the need to increase “the quality of public spending,” promoting competition, impartiality, and transparency, and allowing civil society control of the procurement process. A warning is raised to stimulate actions to combat the occurrence of fraud.

Considering the amount of funds involved in these public bidding processes, there is a clear need to understand the dynamics of this system, which can feed important corruption schemes if cover-ups, cartels and collusion are not detected and neutralized. Through this study, we also aimed to stimulate improvement actions and, above all, to stimulate new research in order to map the occurrence of frauds and verify causes, consequences, and ways to avoid them.

The main limitation of this study is the impossibility of applying the Z-test to make more robust conclusions. In addition, it is important to emphasize that one cannot completely rule out the possibility that the results obtained, instead of revealing evidence of fraud, indicate a possible occurrence of persistent errors in the attribution and/or accounting of values (Costa et al. 2012). In order to obtain an even greater degree of certainty regarding the presence of fraud, further study is required.

A probable cause for these possible frauds and anticompetitive practices may be the lack of mechanisms to identify cheating or attempts to cheat the systems that operate the electronic biddings and, consequently, the rules of the biddings, and this could be mitigated with tools for detection before the signing of contracts, i.e., between the end of the bidding and contracting, resulting in no loss to public coffers.

In this sense, TCU’s recommendation is important to improve preventive controls, which include good governance system, fraud and corruption risk management, anti-fraud/anti-corruption training, and technological devices for monitoring and detecting evidence of these practices.

Further studies based on the Economics of Corruption, on issues involving fraud detection and the dynamics of the corruption process are also recommended, in order to understand the process and make corruption unfeasible or untimely. Possible directions for a future study would be to explore external events, in the analyzed period, that would facilitate or hinder fraud, such

as political or investigative events that inhibit corruption for a period of time. These time frames could be tested separately using the NB-Law.

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