A Comparative Study Between the Brazilian Stock Market and Cryptocurrencies

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***Abstract*—**The Brazilian Stock Market has been experiencing an increase in trading volume, and this shows an improvement in indices. This phenomenon is due to the adoption of Corporate Governance practices, improvement in institutional environments, and greater liquidity in national markets. In this scenario, blockchain technology has become popular in recent years, with various applications, ensuring transaction identification, authenticity, reliability, transparency, equity, and interoperability, along with the emergence of smart contracts. However, the most well-known cryptocurrency is Bitcoin, followed by Ethereum, which was the first to allow the use of smart contracts, and Solana, created in 2018, already holds the fourth position, with great expectations for future growth. The popularization of this asset class may represent an investment opportunity; on the other hand, there is research on its possible relationship with other markets and assets, such as gold, the dollar, or even the Dow Jones index. However, the literature on this subject lacks broader research regarding the Brazilian economy, which, being less stable than those markets known as strong, may present different results. This is the aim of the research to compare three cryptocurrencies (Bitcoin, Ethereum, and Solana) with the Brazilian stock market by means of the non-parametric statistical test Kolmogorov-Smirnov.

Keywords*—Bitcoin, Kolmogorov-Smirnov, Brazilian Stock Market, Cryptocurrencies*

I. Introduction

According to [2012], blockchain technology has become popular in recent years due to its potential applications in various areas. It offers the advantage of being a decentralized method, what allows transactions to be made directly between parties, eliminating central banks or intermediaries, and this method ensures data integrity, anonymity, and immutability. Among these applications, digital currencies or cryptocurrencies have gained massive popularity due to their market values (volatility), ongoing regulatory efforts by some countries, and the proliferation of new currencies.

These digital currencies are encrypted, operate on a peer-to-peer network to facilitate digital exchange, and were developed in 2008, and propose a digital revolution in the payment system, as stated by [5]. Transactions can be completed in minutes, which aid in emergency responses, for example.

Bitcoin, the most well-known and first-created cryptocurrency, proposes a shift from a centralized to a decentralized payment system, with no backing from any central bank. This eliminates territorial barriers and transaction fees, allowing people without bank accounts to conduct transactions with just a mobile device and internet connection.

Indeed, Ethereum allowed the idea of Bitcoin to be extended to other sectors of the economy through the creation of smart contracts, making it the second largest cryptocurrency today [23]. Smart contracts consist of a series of rules that run on the blockchain [24], and through them, it is possible to reduce intermediaries and bureaucracy, as they allow the execution of contracts that were previously done physically, in a digital form, which ensures transparency and immutability. Some areas where these smart contracts have already been successfully applied include: healthcare, the Internet of Things, the insurance industry, notary and registry offices, the financial system, reduction in operacional costs, among others [24, 25], what allows for significant gains in sustainability and efficiency is the monitoring of data, as it enables the reduction of operational costs, minimizes environmental impact, and fosters the development of innovative applications and services [25].

On the other hand, this rapid growth has created some scalability issues, such as the transaction execution time, the block size limit of transactions that can be created, a potential increase in transaction fees, and the increasing complexity of mining as the number of transactions grows, which leads to a higher demand for resources and specialized hardware for processing. To address some of these problems, Solana was launched in 2018, and compared to older cryptocurrencies and its short period of existence, it is already the fourth largest cryptocurrency in the world, with great potential for growth and appreciation in the coming years [22].

As they are not a physical product, their value are generated as users engage in various transactions, such as trading or store of value. Examples include the situation in Argentina when the population faced limitations on converting currency to dollars [9], or during the Brexit vote for the exit of the UK from the European Union [3]. This ease of exchange, without the need to visit authorized agents or research exchange rates, coupled with the ability to use digital currencies online, makes them a faster and more agile solution [5].

Research has been conducted on whether Bitcoin correlates with other indices or currencies. For instance, [10] investigate correlations between Bitcoin value fluctuations

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and the indices of G7 (Germany, Canada, France, Italy, United States, Japan, and United Kingdom) and BRICS (Brazil, Russia, India, China, and South Africa) stock exchanges. [15] examine cryptocurrency efficiency by creating an index of the 30 largest digital currencies and comparing it with the American Dow Jones index. [14] study risk propagation between the Bitcoin market, crude oil, and six other traditional markets (American stocks, Chinese currency, US Treasury bonds, gold, bonds, and US currency).

Thus, the general objective of this study is to compare Bitcoin, Ethereum and Solana volatility and correlation with the Brazilian stock market and its local currency, the real, by means of the Kolmogorov-Smirnov non-parametric statistical test, a statistical method where the data or population lacks characteristic structures or parameters.

This research is relevant because most existing studies compare cryptocurrencies with already strong and established economies, while the Brazilian economy, like that of many other countries, it is still under development, and it faces internal issues such as corruption, social problems, and low education levels in many regions, which are not commonly present in already developed countries. Consequently, the country tends to feel changes in the macro and microeconomic scenario more intensely, bringing greater volatility to the local currency and stock market. Cryptocurrencies could represent an opportunity for store of value during times of high instability if they were to demonstrate greater stability. Additionally, few studies analyze cryptocurrency market behavior in relation to other parts of the economy.

One key difference between comparing the cryptocurrency market with the traditional stock market is that the traditional market operates within a specific schedule and operating days, as well as having regulatory bodies and central banks, some of the major traditional stock markets are: New York Stock Exchange (NYSE), Nasdaq, Shanghai Stock Exchange, EuroNext, Japan Exchange Group, Shenzhen, Hong Kong, Bombay Stock Exchange, London Stock Exchange, and Toronto Stock Exchange. On the other hand, cryptocurrencies can trade 24/7 and there are no regulatory bodies or central banks. This continuous operation leads to greater volatility with regard to events, which may be reflected in quotes on days when the traditional market is closed.

The methodology used is exploratory, where data extraction from the Ibovespa is performed through the Python library yfinance, and its grouping with the data of the cryptocurrencies Bitcoin, Ethereum, and Solana. It is necessary to preprocess these data, as they do not have opening and closing times, making it possible to trade every day, unlike stock markets which have specific days and times for trading. After grouping and filtering the data to only include those with movements on the same days, the Kolmogorov-Smirnov test is performed for each cryptocurrency in relation to the Brazilian index Ibovespa.

The choice of cryptocurrencies was made considering Bitcoin as the largest and most famous, Ethereum as the second largest, and Solana due to its rapid growth and future potential.

II. Literature Review

The theoretical framework addresses the particularities of the Brazilian stock market, Bitcoin, Ethereum e Solana and probability distributions using the Kolmogorov-Smirnov (KS) test. Thus, the section on the Brazilian stock market addresses its growth since its inception, making a comparison with the cryptocurrencies discussed. The parts related to each cryptocurrency cover their particularities, creation, and purpose. Finally, the part about the KS test explains its functioning and usage.

A. Brazilian Stock Market

The Brazilian stock market, also known as B3 (B3 Brasil Bolsa Balcão S.A.), is the main financial exchange in Brazil. The establishment of the stock market and shares in Brazil dates back to 1817, as referenced in [17], and in the 1990s, there were several exchanges in the country, gradually unified into a single one to facilitate transactions and regulations. Today, it counts with more than 400 listed companies, that represents various sectors of the economy such as finance, education, healthcare, agribusiness, among others.

It plays a crucial role in the economy of the country, facilitating the trading of stocks, commodities, and other financial instruments. To understand the dynamics, regulations, and trends of the Brazilian stock market is essential for evaluating its performance and interactions with other financial assets [17].

[8] mentions that economic development is fundamental for the growth of any country, as it creates liquidity and enables the financing of companies and businesses. According to [4], the capital market in Brazil experienced expansion in the 1990s, and the number of investors has been growing every year due to the ease of investing, reduced brokerage fees, and the possibility of higher gains compared to savings accounts, for example. In 2023, the number of investors in B3 reached 19 million, an increase of 46% compared to 2021 [16], with daily transactions amounting to approximately R$ 36.981 billion in January [22], which demonstrates a significant year-on-year increase in transactions due to the influx of new investors. To facilitate investment in a basket of assets and also to track daily trading volume in the Brazilian market, an index called Ibovespa (Ibov) was created, which currently consists

of the 91 main Brazilian stocks, used to demonstrate the overall market volatility. There are some rules for companies to be included, such as transaction volume, market value, level of corporate governance, and each one has a weight, with the index being updated from time to time.

According to [20], the Ibovespa is calculated in real-time and represents approximately 80% of the trading volume on the Brazilian stock exchange, which reflects not only the daily fluctuations in buying and selling of stocks, but also reflects the local macroeconomic and political scenario.

In order to compare with the proposed cryptocurrencies, Table I shows how much the Ibovespa index has risen since its inception, as well as Bitcoin, Ethereum, and Solana, where it can be observed that Ibovespa took more than 50 years to double in value, whereas the cryptocurrencies, in a much

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shorter time, have doubled their value by approximately 50 times, as is the case with Bitcoin.

TABLE I. % APPRECIATION OF ASSETS SINCE THEIR INCEPTION

	Year of Creation	*%*
Ibovespa	1968	+200.59
Bitcoin	2008	+30,684.82
Ethereum	2013	+52,403.27
Solana	2018	+479,40

B. Bitcoin

According to [10], Bitcoin is a liberal decentralized financial system that allows financial transactions to be carried out without the intermediary of banks, brokers or regulatory entities such as the Central Bank. It was created by [11], a name that to this day is unknown whether it belongs to a company, a person or a group of programmers, who presented the idea as a payment system based on cryptography where transactions would be made based on the trust of network nodes.

Its value is then based on the number of available coins (which are created as transactions and blocks are made), within a finite limit, and on the digital transactions that are being executed. This is carried out within a blockchain network, similar to a ledger, keeping all transactions transparent and immutable, according to [1].

Since then, several other currencies have emerged, with Bitcoin having established itself as the largest, with the highest volume of transactions and which has already reached the highest market value, above 65 thousand dollars in 2021.

C. Ethereum

Ethereum was created in 2015 and is considered the second largest cryptocurrency in the world, right behind Bitcoin [23]. Its prominence stems from the possibility of creating smart contracts, which allow two or more parties make agreements digitally and without intermediaries, extending the function of Bitcoin to other sectors.

It also enables the creation of other decentralized applications (dApps), and its transaction completion time is much shorter than with Bitcoin, which takes about 10 minutes, while Ethereum takes about 20 seconds.

On the other hand, it faces scalability issues and often charges high fees during periods of high demand, a problem that has been investigated for the launch of future versions [23].

D. Solana

According to [21], Solana is a public blockchain platform that was launched in April 2018, aiming to increase scalability compared to other cryptocurrencies without compromising their security and decentralization. Like Ethereum, it supports smart contracts. Unlike Ethereum, smart contracts on Solana can be written in any programming language, which also contributes to its rapid growth.

Thus, despite being created relatively recently (compared to other cryptocurrencies), it is seen as the fourth largest cryptocurrency with a great potential for appreciation, having appreciated by more than 34% in just one week [22]. Therefore, this cryptocurrency was chosen for analysis to determine if the launch time has any influence on the proposed tests.

E. Probability Distribution

According to [13], a probability distribution can be understood as a function that indicates the possibility of different events occurring within a set of observations, and it can be either discrete or continuous. Discrete distributions can be counted, while continuous distributions occur within a certain range and cannot be presented in a tabular form.

They can also be of the normal or non-parametric type, with normal distributions generally having a bell-shaped curve and being more commonly found in nature. As [13] state, they are typically defined by a mean and a standard deviation. On the other hand, non-parametric distributions are often encountered, for example, in the financial market, such as the application of the Kolmogorov-Smirnov test.

Based on this, the correct identification of distributions allows for the selection of the best analysis according to the objective of the study, as applying the wrong method to a data set can yield unsatisfactory and unreliable results.

Probability distributions are also used to try to predict asset prices using time series and linear equations, as well as for portfolio modeling and decision-making, where data mining or artificial intelligence techniques can also be employed.

F. Kolmogorov-Smirnov Test (KS)

The Kolmogorov-Smirnov test (or KS test, named after the Russian mathematicians Andrei Kolmogorov and Nikolai Smirnov) is used to test the equality of probability distributions, being employed for comparison of 2 samples (bivariate) or of a sample with a reference value (univariate) [6].

Thus, the objective of the test is to quantify the distance between the distributions, with the null hypothesis (H0) being that the sample is drawn from the distribution, in the case of the univariate, or that both are part of the same distribution, in the case of the bivariate [6]. This test can be applied in various software packages or by developing routines by means of programming languages, such as Python, where the test can be applied using the scipy.stats.kstest function[1].

The choice to use the KS test was made because for samples with a size equal to or greater than 30, it is advisable to use the KS test, whereas the Shapiro-Wilk test, for example, is recommended to use with smaller data dimensions, as referenced in [18].

The formula to calculate the KS is:

$$D = \max|Fn(x) - F(x)|$$

Where:

- D is the value of the test statistic,
- Fn(x) is the empirical distribution function of the sample,

1 https://docs.scipy.org/doc/scipy/reference/generated/scipy.tats.kstest.html

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- F(x) is the theoretical distribution function, usually the CDF (Cumulative Distribution Function) of the distribution being tested.

The value of D is compared with the table of critical values to determine if there is a sufficient evidence to reject the null hypothesis that the two samples come from the same distribution.

In practice, the KS test allows us to verify if the volatility of the Ibovespa has any similarity with the volatility of Bitcoin, Ethereum, or Solana, which enables investors to make better-informed decisions regarding the allocation of their assets.

III. Similar works

Among some of the similar works found, the highlight is on the comparison of cryptocurrencies, typically Bitcoin, with some other index or indicator, such as the dollar, stock market indices like the Dow Jones, as seen in the aforementioned works by [15] and [10].

In addition to these studies, [14] examined the risk propagation among the Bitcoin market, crude oil, and six other traditional markets (US stocks, Chinese currency, US Treasury bonds, gold, bonds, and US currency) between 2019 and 2020, a period that also included the Covid-19 pandemic. Among other methods, they used the Kolmogorov-Smirnov test, and the authors found that during this period, the risk of all markets increased, suggesting caution to investors during times of uncertainty.

[2] and [7] compared the correlation between cryptocurrencies and different currencies such as the dollar, euro, yen, pound, among others. They concluded that the correlation between the assets is practically zero and that there is no dependence between the groups.

The Kolmogorov-Smirnov test has also been used in the verification of criminal transactions, as seen in the work of [19], where the Kolmogorov-Smirnov test, Anderson-Darling test, and Crame-von Mises criterion were used to verify if transactions on the Bitcoin blockchain network originate from illegal sources. The BABD-13 database was used to identify these addresses and serve as a test point. Of the three applications, the Kolmogorov-Smirnov test had the best result in detecting illegal addresses, while the Anderson-Darling test performed better in detecting legal addresses.

These studies are relevant as they allow us to see other comparisons that have already been made and by what method, besides enabling a better understanding of cryptocurrencies and how they relate to the traditional stock and exchange markets. Moreover, knowing the correlation or lack thereof between these means may enable investors to choose investments with lower risk during times of political or economic instability.

Furthermore, it can be seen that the Kolmogorov-Smirnov test has been considered relevant by other authors in comparing data that is non-parametric, such as those produced by the fluctuation of asset and currency values.

IV. Methodology

The methodology used is exploratory, where data acquisition and pre-processing were performed, followed by the bivariate application of the KS test. All development was done using the Python programming language and the libraries numpy [2], pandas [3], scipy [4], datetime [5], matplotlib [6], and yfinance[7]. The numpy library handles large data in formats such as dataframes and arrays, matplotlib is used for generating graphs, datetime was used to convert the timestamp to a readable format, pandas is responsible for reading data from text files, scipy has the implementation of the KS method, and yfinance was used to obtain data for the Brazilian index Ibovespa and other assets.

The data preparation was done independently for each cryptocurrency with which we worked, as their creation dates are different. They needed to be prepared to have the same dates as the Ibovespa database.

The Ibovespa data was obtained via the yfinance library from the Yahoo Finance website, representing the official quotes of the index, and the choice of this method of obtaining data was due to the site already having an API that easily provides the information. This eliminates the need to create a webcrawler for the official pages of the Brazilian stock exchange B3, as the API already returns the following data: Date, Open, High, Low, Close, Volume, and Adj Close. From the information obtained, only the adjusted closing value (Aj Close), which represents the closing value of the asset on the day, was used, and the other values were discarded.

Since the quotes presented by Yahoo Finance are identical to the official quotes, there are no null or blank values. Therefore, no value from the Ibovespa needed to be discarded, grouped, or treated.

A. Bitcoin and Ibovespa

Data collection was carried out in 2 stages. First, historical Bitcoin data was obtained, followed by the Ibovespa index data for the same period, as mentioned above. Bitcoin data was obtained directly from the Kaggle website[8] (which is a site that has various databases already compiled in csv format, therefore, it was not necessary to manually acquire the data from any cryptocurrency exchange), which already has the compiled historical database, covering the period from Jan 2012 to May 2021, with minute-by-minute updated data. The dataset includes Timestamp (Unix time), Open, High, Low, Close, and Volume, with some values as NaN, indicating a possible API failure in capturing the data at that moment. In total, 4,857,377 data points were obtained, with null (NaN) values disregarded, leaving 3,613,769 data points.

Since the data was obtained from Kaggle, in this case no additional cleaning was required other than the exclusion of

2 https://numpy.org/
3 https://pandas.pydata.org/
4 https://scipy.org/
5 https://docs.python.org/3/library/datetime.html
6 https://matplotlib.org/
7 https://pypi.org/project/yfinance/
8 https://www.kaggle.com/datasets/mczielinski/bitcoin-historical-data

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null values, which is the main advantage of using the dataset provided by the site.

The Ibovespa data was obtained via the yfinance library from the Yahoo Finance website, considering the same period, totaling 2,263 data points, and only the date and adjusted closing value (Adj Close) columns were kept, discarding the others.

Due to a much larger amount of Bitcoin price data, as it represents minute-by-minute asset acquisition, it was necessary to aggregate values by date and keep the value of the median daily quotation to normalize the dataset with the same pattern as the Ibovespa index, resulting in 3,376 data points. The difference with the Ibovespa is that Bitcoin operates every day of the week, 24 hours a day, while the Brazilian stock market operates only on business days during a certain period (usually from 10 a.m to 5 p.m), not trading on weekends, holidays, and overnight.

To solve this problem, the two datasets were merged, considering only the days when both had quotation values, resulting in a total of 2,260 data points as final population to the follow tests. However, when generating the initial graph, a significant interval gap between the assets was observed because the Ibovespa data is in Brazilian real, while Bitcoin price is linked to the dollar.

To solve this problem, the Brazilian real versus dollar exchange rate data was obtained through the yfinance library for the same period mentioned, and its median was calculated. All quotation values were then multiplied by the obtained median value to approximate the Ibovespa value to that of the dollar within the proposed period. The preliminary graph with the values can be viewed in Figure 1, where the green line corresponds to the Bitcoin value, the orange line to the adjusted Ibovespa, and the blue line to the Ibovespa in real.

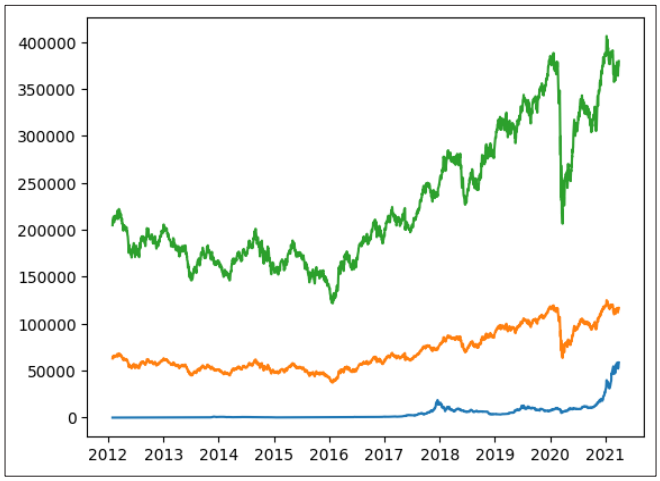

Fig. 1. Generation of the Bitcoin x Ibovespa x Adjusted Ibovespa quotation chart. Legend: Green: corresponds to the value of Bitcoin; Orange: corresponds to the value of the adjusted Ibovespa; Blue: corresponds to the value of the Ibovespa in real terms.

B. *Ethereum and Ibovespa*

The Ethereum data was obtained from the Kaggle[9] platform, which already has it in compiled csv format. Upon downloading the database, it comes in 3 files: one with daily movements, one with minute-by-minute movements, and one with hourly movements, that covers the period from May 9, 2016, to April 15, 2020. We opted to work with the daily data, resulting in 1,438 rows and 8 attributes: Date, Symbol, Open, High, Low, Close, Volume ETH, and Volume USD.

We removed all columns except for Date and Close, which represent the daily closing value of the asset. The dataset contains no null values, leaving us with 1,438 records after this initial preprocessing step.

Since the data was obtained also from Kaggle, in this case no additional cleaning was required, and the dataset did not have null values, so no data treatment was necessary.

The steps for obtaining the Ibovespa data are the same as described above, with only the collection period changed to start from May 9, 2016, to April 15, 2020. The acquisition also considered the adjusted Ibovespa base and in Brazilian real.

After unifying the databases, considering common days across all databases, we were left with a population of 975 data points, as shown in Figure 2. The green line corresponds to the Ethereum value, the orange line to the adjusted Ibovespa, and the blue line to the Ibovespa in Brazilian real.

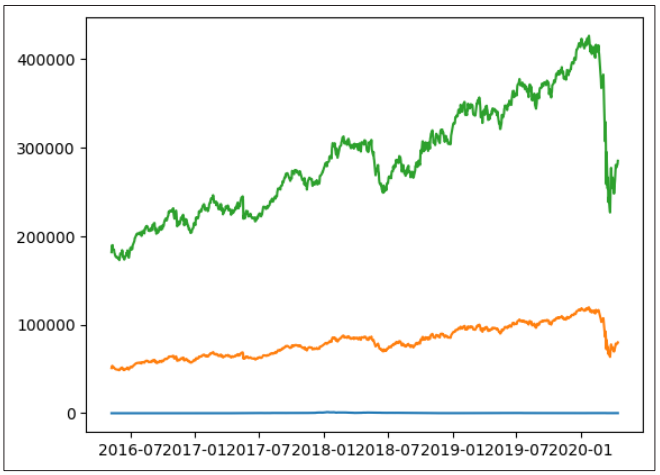

Fig. 2. Generation of the Ethereum x Ibovespa x Adjusted Ibovespa quotation chart. Legend: Green: corresponds to the value of Ethereum; Orange: corresponds to the value of the adjusted Ibovespa; Blue: corresponds to the value of the Ibovespa in real terms.

C. *Solana and Ibovespa*

For Solana, a database provided also by Kaggle[10] was also utilized, resulting in 1,402 data points spanning from April 17, 2020, to February 17, 2024, compiled on a daily basis. The dataset contains the following information: Date, Open, High, Low, Close, Adj Close, and Volume. Only the Adj Close and Date columns were retained, and as with the Ethereum dataset, there were no null values and no additional data treatment was necessary.

For the Ibovespa, the same steps of acquisition mentioned previously were followed, considering the same period as the Solana data. After merging the dates present in the databases, 952 data points remained, and the preliminary result is presented in Figure 3. The green line corresponds to the value

9 https://www.kaggle.com/datasets/prasoonkottarathil/ethereum-historical-dataset

10 https://www.kaggle.com/datasets/ahmadalijamali/cryptourrenciesprices

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of Solana, the orange line to the adjusted Ibovespa, and the blue line to the Ibovespa in Brazilian real.

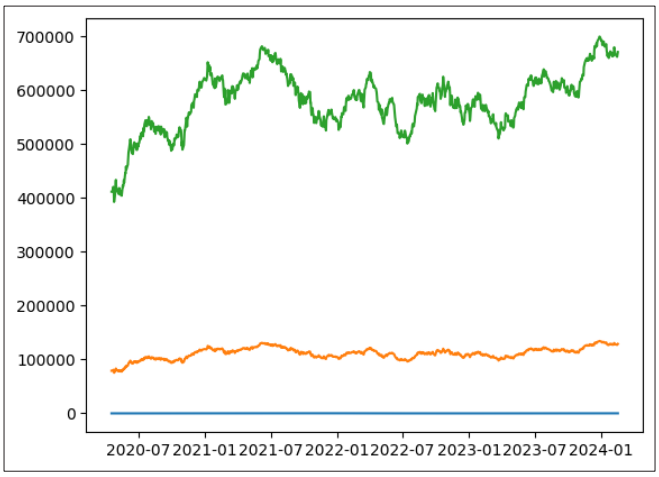

Fig. 3. Generation of the Solana x Ibovespa x Adjusted Ibovespa quotation chart. Legend: Green: corresponds to the value of Solana; Orange: corresponds to the value of the adjusted Ibovespa; Blue: corresponds to the value of the Ibovespa in real terms.

Finally, the KS test was performed for all sets of data, Bitcoin and Ibovespa, Ethereum and Ibovespa and Solana and Ibovespa, considering Ibovespa in real terms and for the adjusted Ibovespa. We use the ktest function from the SciPy library in the Python language.

This test was chosen because the data does not follow a normal distribution, as it exhibits a distribution different from the bell curve. Therefore, solely obtaining means or standard deviations may not be entirely effective in interpreting the information. Thus, the Kolmogorov–Smirnov test is used to compare two samples with each other to verify their equality, which in our case implies they have similar volatility. We did not consider using the Shapiro-Wilk test because it is typically used for smaller datasets.

Finally, the significance test allows for a decision to be made between two or more hypotheses, as it indicates the probability of rejecting the null hypothesis when it is true, considering a p-value of 0.05.

V. *Results*

Just like in the methodology, the results are separated by the sets of databases worked on: Bitcoin Ethereum and Ibovespa, all being compared with the Ibovespa index.

The static value corresponds to the percentage value of the KS test, the static location corresponds to the distance between the empirical distribution function and the measure in the observation, and the p-value is the probability of the value being less than 5%, indicating that the variables have a probability of being part of the same model, contributing to its solution.

A. *Bitcoin*

Thus, Table 2 summarizes the results considering the null hypothesis that the distributions are equal, Table 4 shows the results where the Bitcoin distribution is greater, and Table 3 where the null hypothesis states that the Bitcoin distribution is smaller.

TABLE II. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTIONS ARE EQUAL.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	100	0.0	58901.8
Ibovespa in brazilian real	98.23	0.0	37393.49

TABLE III. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTION OF BITCOIN IS SMALLER THAN THAT OF THE IBOVESPA.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	0	1.0	406412.696
Ibovespa in brazilian real	0	1.0	125077.0

TABLE IV. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTION OF BITCOIN IS GREATER THAN THAT OF THE IBOVESPA.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	100	0.0	58901.8
Ibovespa in brazilian real	98.230	0.0	37393.49

Observing Table 3, it is noted that the p-value is equal to 1, meaning it is equal to the level of significance, where the probability of any element from the sample participating and impacting the model is low, thus lying outside the confidence interval, as it neither impacts nor contributes to the model.

On the other hand, the results from Tables 2 and 4 are identical, demonstrating that Bitcoin may have a distribution greater than or equal to that of the Ibovespa, both in its adjusted version and in Brazilian currency (real), indicating that the study holds a valid significance.

B. *Ethereum*

Table 5 summarizes the results considering the null hypothesis that the distributions are equal, Table 7 shows the results where the Ethereum distribution is greater, and Table 6 shows the results under the null hypothesis that the Ethereum distribution is smaller.

TABLE V. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTIONS ARE EQUAL.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	100	0.0	1292.25
Ibovespa in brazilian real	100	0.0	1292.25

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TABLE VI. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTION OF BITCOIN IS SMALLER THAN THAT OF THE IBOVESPA.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	0	1.0	119528.0
Ibovespa in brazilian real	0	1.0	426021.68

TABLE VII. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTION OF BITCOIN IS GREATER THAN THAT OF THE IBOVESPA.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	100	0.0	1292.25
Ibovespa in brazilian real	100	0.0	1292.25

Similarly to the experiment involving Bitcoin and the Ibovespa index, Table 6 shows a p-value equal to 1, demonstrating that the probability of its participation and impact on the model is low. Also similar to the previous results, Tables 5 and 7 demonstrate that Ethereum has a distribution greater than or equal to that of the Ibovespa, both in its Brazilian real form and in the adjusted form, indicating that the study has a valid degree of significance.

C. Solana and Ibovespa

Table 8 summarizes the results considering the null hypothesis that the distributions are equal, Table 10 presents the results where the Solana distribution is greater, and Table 9 shows where the null hypothesis states that the Solana distribution is smaller.

TABLE VIII. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTIONS ARE EQUAL.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	100	0.0	248.46
Ibovespa in brazilian real	100	0.0	248.46

TABLE IX. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTION OF BITCOIN IS SMALLER THAN THAT OF THE IBOVESPA.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	0	1.0	134194.0
Ibovespa in brazilian real	0	1.0	698466.32

TABLE X. SUMMARY OF RESULTS CONSIDERING THE NULL HYPOTHESIS THAT THE DISTRIBUTION OF BITCOIN IS GREATER THAN THAT OF THE IBOVESPA.

	Static (%)	*pvalue*	*Static Location*
Adjusted Ibovespa	100	0.0	248.46
Ibovespa in brazilian real	100	0.0	248.46

Similarly to the previous studies involving Bitcoin and Ibovespa, and Ethereum and Ibovespa, the result shows that Solana has a greater distribution than or equal to that of the Ibovespa, both in its Brazilian real form and in the adjusted form, with a valid significance (Tables 8 and 10). Meanwhile, in Table 9, the p-value equal to 1 indicates that the contribution of the data to the model is low or of little importance.

This means that the distributions are weakly correlated, which from a practical standpoint, means that if the Ibovespa index is experiencing internal or external pressures and declining, Bitcoin, Ethereum, or Solana could be an option to avoid asset loss or be used as a store of value. Since they are weakly related, this downward volatility would not necessarily impact cryptocurrencies.

Conversely, if Bitcoin, Ethereum, or Solana were experiencing downward volatility due to possible regulation or bans, the Ibovespa index would not necessarily be affected for the same reasons, potentially being used strategically to maintain invested capital with lower risk.

Therefore, knowing whether assets of different types have any correlation can be important for investors to make good decisions not only for profit but also to protect their capital, especially in times of great economic or political instability, such as during wars, uncertainties, or pandemics.

Additionally, Brazil being a developing country may experience events from external sources with varying degrees of intensity, especially significant events like Brexit or the Russia-Ukraine war. This could be considered a positive point as it puts the country outside the radar of macroeconomic uncertainties, that makes it a lower-risk investment possibility in some scenarios, unlike cryptocurrencies, which, is traded globally 24/7, may experience higher volatility during periods of uncertainty.

VI. *CONCLUSIONS*

Blockchain technology has become quite popular, and one of its most well-known applications is Bitcoin, a decentralized virtual currency that ensures transparency and integrity of transactions. As a counterpoint to this popularization, its volatility tends to be high in various periods.

Based on this, the study sought to understand the distance of its curve with the Brazilian stock market, represented by the Ibovespa index, which comprises the main Brazilian stocks. The KS test was then applied under 3 null hypotheses for 3 cryptocurrencies (Bitcoin, Ethereum and Solana): that the distribution of the cryptocurrency is equal to that of the Ibovespa, smaller or larger, considering both the index adjusted in dollars and in Brazilian real.

As final results, the focus of the work is on the distance that the curves represent through the KS test, that is, the greater the distance, the greater the dispersion of the data, leading to the interpretation that they are weakly correlated, or the adherence of one may not influence the other, as the market would like (or desire) it to follow (in the trend of value), ending up with lower (or higher) market values. This is because the calculated value (p-value) is less than 0.05 or 5%, demonstrating that the null hypothesis that cryptocurrencies has a similar distribution to that of the Brazilian market or larger is true, which can be interpreted as markets still in development.

The same result occurs for all three analyzed cryptocurrencies: Bitcoin, Ethereum, and Solana. The test considering that they would be smaller than the Brazilian

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market showed to be unlikely, and for the tests taking into account that the Brazilian market would be greater than or equal to them, similar results were obtained.

As a practical result, the fluctuation of one does not necessarily imply the fluctuation of the other, which can allow investors to protect their capital during times of crisis. Given that Brazil is still a developing country, it usually does not have a significant participation in external events such as wars or international political disputes. On the other hand, when the country experiences instabilities, cryptocurrencies can be a good source of profit or store of value, again enabling investors to protect their wealth.

Based on this, the contribution of the study has a social bias, allowing for greater decision-making and risk management by providing a better understanding of the correlation or lack thereof between different assets. And the choice of the KS test was made because it applies to continuous distributions (as is the case with stocks and their values) and its values are more sensitive near the center of the distribution than to the tails.

As future work, we intend to continue the research by applying other tests focused on non-parametric distributions and also focusing on developing markets, but seeking to extend the analysis to explore additional factors, such as global economic indicators, money supply, inflation rates, public perception, confidence in cryptocurrencies, among others, thereby enriching and broadening the analysis, using this study as an initial basis.

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