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Comparison of the Accuracy of Brown's and Holt's Double Exponential Smoothing in LQ45 Stock Price Forecasting

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Abstract
As of May 2022, 787 stocks are listed on the Indonesia Stock Exchange (IDX), and the number of stock indices in Indonesia to date is 38. One interesting and important stock index is the LQ45 index. The LQ45 index contains 45 stocks that have undergone a selection process with high liquidity and several criteria such as market capitalization, liquidity, company fundamental conditions, and company growth prospects. The forecasting process has two essential things: the data and the correct forecasting method. Two forecasting methods that can be used are Brown and Holt's Double Exponential Smoothing (DES). This study examines two methods with the lowest accuracy error in forecasting the LQ45 stock price data. This research was conducted in 2022 using shares in the LQ45 stock index for six years (2016-2021) as training data (modeling data) and using two months of data (January and February 2022) as testing data. Mean Absolute Percentage Error (MAPE) is used to measure the accuracy of the error. The analysis methods used to compare the MAPE of the two methods are the F test for variance similarity, Boxplot, t-test to test paired means with different variance cases, and Wilcoxon signed rank test to test paired means nonparametric statistics. The result is that the MAPE average with Holt's DES method is smaller than the average MAPE with Brown's DES method. This is supported by the t-test for paired means with different cases of variance and also supported by the Wilcoxon signed exact rank test. Meanwhile, the MAPE standard deviation with Holt's DES method is smaller than the MAPE standard deviation with Brown's DES method. This is supported by the F test to test the variance similarity and visually supported by a Boxplot diagram. From this study, LQ45 stocks with the smallest MAPE value accuracy are ICBP stocks. In general, based on the MAPE value, Holt's DES method is better than Brown's DES method in predicting the prices of stocks in the LQ45 index.

Keywords— double exponential smoothing, brown's method, holt's method, LQ45 stock forecasting

1 Introduction

Investing through stocks is one of the many financial activities accomplished by buyers. Stocks are proof of possession of a business enterprise [1]. Shareholder means the owner of the employer. The bigger the stocks someone owns, the more ownership inside the corporation. Furthermore, stocks are an appealing investment instrument because they offer advantages [2]. In growing nations, shares also play a vital role in the country's progress [3].

The Composite Stock Price Index (IHSG) is a stock marketplace index utilized by the Indonesia Stock Trade (IDX). It's miles regularly referred to as the Indonesian Composite Index (ICI) or the IDX Composite. The index, first used on April 1, 1983, is used as an indicator of stock price movements on the IDX, where this index is the total price of all ordinary and preferred shares within the IDX. The ICI calculation was first started on August 10, 1982, with a value of 100, and at that time, there were 13 stocks. This number has increased exponentially; as of May 2022, there have been 787 stock listings. The IDX has created several stock indexes to represent special interests based on their objectives. At the time of writing, 38 other stock indices were part of the ICI, which had been formed according

to their needs, including the LQ45 stock index. In Indonesia, many stocks are currently listed on the stock exchange, namely 787. Because there are too many stocks to be analyzed to compare these two methods, the researchers only took 45 shares listed on the LQ45 Index. The uniqueness and advantages of the stocks included in this index are generally stocks with high liquidity and large market capitalization.

Two important things need to be considered in the forecasting process: the availability of data and the forecasting method used. Scientists and investors often use two simple forecasting methods: the Brown's Double Exponential Smoothing (DES) method and the Holt's Double Exponential Smoothing (DES) method. Because the list of stocks listed on the IDX is huge, this study focuses on data on stocks that are in the LQ45 stock index, which represents the LQ45 JCI, which were recorded in the period August 2021-January 2022 in accordance with the ANNOUNCEMENT of the LQ45 Index Minor Evaluation Appendix No. Peng-00023/BEI.POP/01-2022, dated January 25, 2022. Here are some of the benefits of a stock index [3]:

1. The index can measure sentiment (conditions) in the market.
2. Stock indexes such as Index Mutual Funds, an ETF, and other derivative products can be used as passive investment products.
3. The index can be used as a reference (benchmark) for an active portfolio,
4. Indices can be used as proxies to measure and develop a return on investment (return), systematic risk, and risk-adjusted performance models.

This study uses shares inside the LQ45 index because these 45 stocks have high liquidity and large marketplace capitalization and are supported via the right enterprise fundamentals. The list of stocks included in LQ45 is in accordance with the LQ45 Index Minor Evaluation Announcement Appendix No. Peng-00023/BEI.POP/01-2022, dated January 25, 2022. This paper aims to compare the accuracy of Brown's Double Exponential Smoothing method with Holt's in forecasting stock prices in the LQ45 index. The measure of accuracy used in this comparison is the MAPE value, where the smaller the MAPE value, the better the accuracy results. The benefits that can be provided from this paper are:

1. For investors, this research can be used as input in making decisions regarding which method to use for forecasting from the two methods studied, namely Brown's or Holt's DES method.
2. For academics, this research is expected to provide added value for the breadth and depth of forecasting and time series analysis.
3. For researchers, this research can provide new ideas and insights related to LQ45 stock, forecasting methods used, and existing statistical analysis.
4. The importance of stock price forecasting is that it will increase profits from stock buying and selling transactions because share owners can know the right time to buy and sell and the expected price for buying and selling. This research focuses on stocks on the LQ45 index because LQ45 stocks have high liquidity. With high liquidity, it is guaranteed that there will always be daily transactions on these stocks.

Many studies on time series data and forecasting topics have been carried out. Forecasting is an essential part of supporting the decisions that will be taken. One of the most frequently used forecasting methods is Brown's Double Exponential Smoothing (DES) model, abbreviated as Brown's DES. Aden and Supriyanti [4] conducted a study to predict the number of new students at Al-Musyarrofah Islamic Elementary School Jakarta using Brown's DES Method in 2020/2021 with an expected result of 64 students [4]. Ferdiansyah et al. conducted a similar study using Brown's DES method for forecasting the inventory of Honda motorcycles at PT. Delta Sari Agung Sidoarjo's warehouse, and the resulting value was 622 motorcycles [5]. Jahring and Pradani conducted forecasting using Brown's DES method to predict Arini's batik cloth demand in October 2014. The prediction results of the demand for Arini's batik cloth with parameter $\alpha = 0.581$ in September 2014 were 10,324 fabrics [6]. Farida et al. forecasted the Human Development Index (IPM) in Bojonegoro Regency using Brown's DES method using training data in the form of HDI data in Bojonegoro Regency for 10 years, namely from 2010 to 2020. The results of this study stated that the parameter value $\alpha = 0.7$ and the MAPE value = 0.376% produce the best forecasting results [7].

Purwanti and Purwadi use inflation data from the official website of Bank Indonesia. This data is used for forecasting the rate of inflation in Indonesia. The forecasting method used is Brown's Double Exponential Smoothing. From the forecasting obtained using this method, the value obtained is MAPE of 10.607% [8]. Another study using DES was also carried out by Marlim and Hajjah, who created an information system to predict inventory at UD Maju Utama, which buys and sells motorcycle spare parts with a specific parameter (α). For oil, the parameter with the best value was obtained $\alpha = 0.2$ with a MAPE value of 9.51%, while for goods with outer tire types, the best parameter was obtained $\alpha = 0.1$ with a MAPE value of 9.49% [9]. Dharmawan and Indradewi also used Brown's DES method to forecast sales of retail goods at the UD Parama Store and obtained MAPE results between 7.99% to 32.42% [10].

Another study using Brown's DES method was conducted by Syahdan and Aisyah, who used it to determine the best parameters for forecasting the Consumer Price Index (CPI) for Tarakan from January to May 2019. From the experiments' results, the best parameter was 0.5 with a value MAPE = 0.670. By knowing the value of the CPI that continues to increase, the decision to purchase the inventory of goods and services should be accelerated to avoid purchases at higher prices [11].

Besides Brown's DES, several previous studies have used Holt's DES forecasting method. Susanto et al. used JCI data from January 1990 to December 2019 of 360 observations obtained from the Yahoo! site. Finance. By using Holt's DES method and data processing using R software, the values α=1 and β=0.02380527 are obtained as smoothing constant values for optimal level and trend estimation so that they can produce good model data plots because they coincide with observational data [12]. Mariana et al. conducted forecasting using Holt's DES method of the Indonesian government's foreign debt. The records used within the model are on authorities' debt overseas from January 2010 to April 2019. Further, an evaluation is likewise needed to predict the quantity of government debt overseas from May to July 2019. From the forecasting model generated, it is found that parameter value α = 0.9275299 and parameter β = 0.02806376, which is optimal and obtained a MAPE value of 1.36% [13].

In addition to discussing each DES method, several studies compare Brown and Holt's DES methods for time-based data forecasting processes; one of them is Muchayan, who examines the use of two different forecasting methods, namely the Brown method and the Holt method, to predict mutual fund NAV price movements. From the calculation results, the data generated by the Holt forecasting method is 1809.657 with a MAPE of 0.644373568, while a forecast with a MAPE value of 0.6104262 is obtained for the Holt method. Seeing the resulting MAPE value, the Holt method has a smaller accuracy of forecasting errors when compared to the Brown method [14]. Rahmawati et al. also tried to research Brown and Holt's DES method to forecast coal production demand for the next six years at Company X. Using the Brown approach, the MAPE fee is 6.74. On the other hand, using the Holt approach, the MAPE value is 5.8157.The Holt method predicts the coal demand level in the next six years more accurately than the Brown method [15].

Bidangan et al. used data on the amount of clean water production in Samarinda City to compare forecasting between Brown's and Holt's DES methods. Brown's one-parameter double exponential smoothing method with parameter α=0,21 produces a forecast with MAPE of 2.9629%. With Holt's two-parameter double exponential smoothing method with parameters α=0.31 and γ=0,92, the estimates with MAPE is 2.9016%. From these results, it can be concluded that the Holt method is more accurate for the clean water forecasting process than the Brown method [16].

1.1 Exponential Smoothing

In statistics, data is measured over a certain period with uniform (same) intervals. This data is called time series data. With much data that depends on time, time series analysis, a branch of statistics, is developed. Time series analysis is a technique that researches time series in terms of the underlying concept and for making forecasts (predictions). Time series prediction/forecasting generally statistical and mathematical models to predict future values based on data from an event that has occurred in the present or past [17].

Several forecasting methods use the Exponential Smoothing method. Exponential Smoothing started with Brown in 1959, followed by Holt and Winter in 1960. Forecasting using the exponential smoothing method calculates the weighted average of previous observations, with the weight decreasing exponentially as the observation time increases [18].

1.2 Brown's Double Exponential Smoothing

Briefly, Brown's Double Exponential Smoothing modeling uses the formula (1) –(3) [6]:

$$A_t = \alpha y_t + (1-\alpha)A_{t-1}$$
$$A''_t = \alpha A_t + (1-\alpha)A''_{t-1}$$
$$a_t = 2A_t - A''_t$$
$$b_t = \left(\frac{\alpha}{1-\alpha}\right)(A_t - A''_t)$$
$$F_{t+m} = a_t + b_t m \quad (1)$$

To initialize the initial value, formula (2) can be used:

$$A_1 = A''_1 = y_1$$
$$a_1 = y_1$$
$$b_1 = \frac{(y_2 - y_1)+(y_4 - y_3)}{2} \quad (2)$$

Brown's DES method finds the value α, say α* which will minimize the MAPE(α) function in the form of formula (3):

$$MAPE(\alpha) = \sum_{i=1}^{n} \left| \frac{A_i - F_{i,\alpha}}{A_i} \right| \quad (3)$$

Then the value of α* is used for the forecasting process.

1.3 Holt's Double Exponential Smoothing

Briefly Holt's Double Exponential Smoothing modeling uses the formula (4)-(6) [19]:

$$S_t = \alpha y_t + (1-\alpha)(S_{t-1} + G_{t-1})$$
$$G_t = \beta(S_t - S_{t-1}) + (1-\beta)G_{t-1}$$
$$F_{t+m} = S_t + mG_t \quad (4)$$

To initialize the initial value, formula (5) can be used:

$$S_0 = y_1$$
$$G_0 = 0 \quad (5)$$

Holt's DES method finds the value (α,β), say (α*,β*) that will minimize the MAPE(α,β) function in the form according to formula (6):

$$MAPE(\alpha, \beta) = \sum_{i=1}^{n} \left| \frac{A_i - F_{i,\alpha,\beta}}{A_i} \right| \quad (6)$$

Then, the value (α*,β*) is used for forecasting.

1.4 Forecasting Accuracy

The MAPE measure (MAPE = Mean Absolute Percentage Error) is used to measure the accuracy of the forecasting process. MAPE, additionally called mean absolute percent deviation (MAPD), measures the predictive accuracy of statistical forecasting methods. Usually expresses accuracy as a ratio determined by formula 7.

$$MAPE = \sum_{i=1}^{n} \left| \frac{A_i - F_i}{A_i} \right| \quad (7)$$

wherein Ai is the real value, and Fi is the forecasted value. In this research, n = 39 was used, which is precisely the quantity of information for two months (January to February 2022). MAPE is likewise, on occasion, expressed as a percent, the above equation multiplied by 100%. The distinction between Ai and Fi is divided by using the actual cost of Ai. The price in this calculation is added up for each forecasted point in time and split with the aid of the number of all points, i.e., n. In this research, MAPE (Mean Absolute Percent Error) is the accuracy measure used. MAPE is used because the size of the forecasting variable is a significant factor in evaluating the accuracy of the forecast. In addition, MAPE indicates how large the percentage of forecast error is compared to the actual value of the existing time series data.

Several studies have compared the DES method of Brown and Holt for the time-based data forecasting process, but there has never been a study that has reached the two methods to data on LQ45 stocks. Based on the results of existing studies, the authors compare Brown and Holt's DES method for forecasting stock prices that fall into the LQ45 category on the IDX. The contributions and differences of this study compared to previous studies are:

1. In the studies that have been conducted on Brown and Holt's DES method, most researchers use only one case or one entity. This study uses the case of 45 stocks that have different price movements in the Indonesian stock market.
2. This study compares two forecasting methods based on the accuracy of the MAPE value for each LQ45 stock so that from a particular stock, it can be seen which stock has the smaller MAPE value.
3. In general, to see which method performs better in predicting the LQ45 stock price based on the accuracy of the MAPE, the researcher presents descriptive statistics in the form of a boxplot diagram and several statistical tests, namely:
    - F-test to test the similarity of variance
    - T-test to test paired means with different cases of variance
    - Wilcoxon signed-rank test to test statistically nonparametric paired mean.

While all the research mentioned above did not carry out these statistical tests.

Finally, this research expects to see the difference in accuracy between the two existing forecasting methods, namely the Brown and Holt double exponential smoothing method. A better forecasting method can be obtained by looking at the difference in accuracy. The structure of this article is as follows: the first part is the introduction, which includes the history of the problem, the techniques offered, and the goals and advantages of the research. The second

part is Research Methodology, which discusses the research methods in more detail. The following section is a literature review that references various related studies and continues with Results and Discussion, which contains the research results and a complete analysis. Lastly, it closes with the Conclusion, the concluding part of this article, and suggestions for further research.

2 Research methods

This study uses data on the IDX (Indonesian Stock Exchange). This data is divided into two types: in data (training data) and out data (test data). In-data is used to create a time-series forecasting model, and out-data is used to test the value of the forecast results. The specific question that will be answered and explained in this research is, between the two exponential smoothing methods, namely the Holt method and the Brown method, which will produce better accuracy using time series data for LQ45 index stocks. The stages of the research carried out are as follows:

1. Researchers take and use LQ45 stocks for six years (2016-2021) as a dataset or training data for modeling. The test data uses two months, namely in January and February 2022. The suitability of LQ45 stocks in this research is because the stocks included in this index are generally stocks with high liquidity and large market capitalization, so these stocks are always traded on stock exchange days.
2. The writer creates Brown's DES model by using the parameter value (α^*), which will minimize the MAPE value.
3. The author creates Holt's DES model based on the parameter values (α^*,β^*), which will minimize the value of MAPE.
4. Researchers carry out the forecasting process using Brown and Holt's DES model and calculate MAPE_B and MAPE_H.
5. The author compares the values of MAPE_B and MAPE_H to determine which of the two models is more accurate in forecasting. This accuracy is measured by the criterion of the smaller MAPE value between these two models.
6. Performing some statistical analysis to compare the accuracy of the two forecasting methods based on the MAPE, namely
    - View numerical descriptions of both forecasting methods.
    - Testing the similarity of the variances of the two forecasting methods.
    - Testing the similarity of means in pairs of 2 forecasting methods.
    - Draw Boxplot diagrams.
7. Testing the paired means is statistically nonparametric.

3 Results and Discussion

In this section, parameter modeling from the Brown and Holt methods and the forecasting results of LQ45 stock data will be presented.

The first step in modeling is to find the value of the parameter α which will minimize MAPE from formula (5) with Fi using equation (1). The α value that minimizes MAPE is called the α^* value and this value is used for the forecasting process. The accuracy of this forecasting process is calculated using the MAPE_B value as in formula (5), namely the difference between the actual data from the security and the forecast value obtained. Using the MAPE_B symbol indicates that this accuracy is derived from Brown's DES method. MAPE_B calculations were carried out as many as n = 39, namely the amount of data for two months (January - February 2022). The Alpha* values and MAPE_B values are presented in Table I.

Table I. MAPE Value Of LQ45 Stock for Forecasting with Brown DES from January to February 2022

No.	Stock Code	Alpha*	MAPE_B value	No.	Stock Code	Alpha*	MAPE_B value
1.	ADRO	0.436672755	0.164528	24.	INTP	0.506362090	0.293129
2.	AMRT	0.358648631	0.128085	25.	ITMG	0.499737728	0.066705
3.	ANTM	0.486417838	0.125842	26.	JPFA	0.502114980	0.250018
4.	ASII	0.397536066	0.030115	27.	KLBF	0.507517202	0.041826
5.	BBCA	0.423732548	0.07791	28.	MDKA	0.519676420	0.029896
6.	BBNI	0.474844406	0.058326	29.	MEDC	0.509788993	0.266424
7.	BBRI	0.491370401	0.019846	30.	MIKA	0.506719468	0.047676
8.	BBTN	0.482088944	0.032252	31.	MNCN	0.502123809	0.03967
9.	BFIN	0.481139175	0.172441	32.	PGAS	0.499571494	0.067773
10.	BMRI	0.430458534	0.070009	33.	PTBA	0.496859646	0.066933

No.	Stock Code	Alpha*	MAPE_B value	No.	Stock Code	Alpha*	MAPE_B value
11.	BRPT	0.501447931	0.17177	34.	PTPP	0.495288332	0.070641
12.	BUKA	0.400594543	0.074427	35.	SMGR	0.499910308	0.050136
13.	CPIN	0.512856958	0.04848	36.	TBIG	0.511142213	0.115057
14.	EMTK	0.513308372	0.177603	37.	TINS	0.500705227	0.066604
15.	ERAA	0.508826168	0.060473	38.	TKIM	0.499893876	0.097734
16.	EXCL	0.515345868	0.17122	39.	TLKM	0.507816071	0.126373
17.	GGRM	0.503387710	0.032095	40.	TOWR	0.520013329	0.034948
18.	HMSP	0.507726226	0.030855	41.	TPIA	0.500051416	0.086786
19.	HRUM	0.504170225	0.091809	42.	UNTR	0.503405357	0.060275
20.	ICBP	0.508245812	0.009589	43.	UNVR	0.504082362	0.049561
21.	INCO	0.497761369	0.028913	44.	WIKA	0.504843621	0.058926
22.	INDF	0.502478659	0.040169	45.	WSKT	0.501025504	0.623978
23.	INKP	0.502956316	0.033737				
		Average	0.099145844				
		Stan. Dev.	0.104142475				
		Minimum	0.009589				
		Maksimum	0.623978				
		Median	0.066705				

Table I shows that the average forecasting error for LQ45 shares is 9.9146%, with a standard deviation of 10.4142%. The stock with the lowest forecasting error is ICBP, at 0.9589%, while the highest is WSKT, with a value of 62.3978%. The stock code ICBP represents PT. Indofood CBP Sukses Makmur Tbk is a company that manufactures noodles and food ingredients, culinary food products, biscuits, snacks, nutrition and special foods, packaging, trade, transportation, warehousing and cold storage, and others. So ICBP shares are included in the Consumer Good stock group, as shares in this group have a low MAPE because the price of these shares does not fluctuate and is not cyclical.

The second step in modeling is to find the parameter values (α,β) that will minimize MAPE from formula (5) with Fi using equation (3). The value (α,β) that minimizes MAPE is called the value (α*,β*), and this value is used for the forecasting process. These values are presented in Table II.

Table II. Alpha* And Beta* Values of LQ45 Stock for Forecasting with Holt's DES (2 Parameters)

No.	Stock Code	Alpha*	Beta*	No.	Stock Code	Alpha*	Beta*
1.	ADRO	0.957971650	0.01	24.	INTP	0.963994201	0.000680535
2.	AMRT	0.884530136	0.01	25.	ITMG	1	0
3.	ANTM	0.994844629	0.01	26.	JPFA	1	0
4.	ASII	1	0	27.	KLBF	1	0
5.	BBCA	0.907109452	0.000179258	28.	MDKA	1	0
6.	BBNI	1	0	29.	MEDC	1	0
7.	BBRI	1	0	30.	MIKA	1	0
8.	BBTN	1	0	31.	MNCN	1	0.001226440
9.	BFIN	1	0	32.	PGAS	1	0
10.	BMRI	1	0	33.	PTBA	1	0
11.	BRPT	1	0	34.	PTPP	1	0.001567954
12.	BUKA	1	0.051828994	35.	SMGR	1	0
13.	CPIN	1	0	36.	TBIG	0.927872207	0
14.	EMTK	1	0	37.	TINS	1	0
15.	ERAA	0.9864038261	0	38.	TKIM	1	0
16.	EXCL	1	0	39.	TLKM	1	0
17.	GGRM	1	0	40.	TOWR	1	0
18.	HMSP	0.9271739326	0.013767891	41.	TPIA	1	0.028004304
19.	HRUM	0.9888739326	0.003899998	42.	UNTR	0.944540164	0
20.	ICBP	1	0	43.	UNVR	0.952110055	0.005816170
21.	INCO	1	0	44.	WIKA	1	0

No.	Stock Code	Alpha*	Beta*	No.	Stock Code	Alpha*	Beta*
22.	INDF	1	0	45.	WSKT	1	0
23.	INKP	1	0				

The accuracy of this forecasting process is calculated using the MAPE_H value as in formula (5), namely the difference between the actual data from the security and the forecast value obtained. The use of the MAPE_H symbol indicates that this accuracy is derived from Holt's DES method. MAPE_H calculations were carried out as many as n = 39, namely the amount of data for two months (January - February 2022). The MAPE_H values are presented in Table III.

Table III. MAPE Value of LQ45 Stock for Forecasting with Holt's DES (2 Parameters) from January - February 2022

No.	Stock Code	MAPE_H Value	No.	Stock Code	MAPE_H Value
1.	ADRO	0.065012	24.	INTP	0.093249
2.	AMRT	0.065896	25.	ITMG	0.063146
3.	ANTM	0.155992	26.	JPFA	0.046944908
4.	ASII	0.025151	27.	KLBF	0.028499845
5.	BBCA	0.057326	28.	MDKA	0.03549084
6.	BBNI	0.081965	29.	MEDC	0.116382281
7.	BBRI	0.036583	30.	MIKA	0.034653
8.	BBTN	0.029343	31.	MNCN	0.041188
9.	BFIN	0.078696	32.	PGAS	0.031555
10.	BMRI	0.0550091	33.	PTBA	0.050379
11.	BRPT	0.0627768	34.	PTPP	0.048387
12.	BUKA	0.187717172	35.	SMGR	0.032376
13.	CPIN	0.033906	36.	TBIG	0.029995
14.	EMTK	0.164521933	37.	TINS	0.045741
15.	ERAA	0.078161305	38.	TKIM	0.055763
16.	EXCL	0.052403204	39.	TLKM	0.051518
17.	GGRM	0.01796519	40.	TOWR	0.073902
18.	HMSP	0.053706452	41.	TPIA	0.142398
19.	HRUM	0.039382742	42.	UNTR	0.052975
20.	ICBP	0.011147409	43.	UNVR	0.030266
21.	INCO	0.031283935	44.	WIKA	0.036642
22.	INDF	0.013147786	45.	WSKT	0.053583
23.	INKP	0.03549084			
	Average	0.058391505			
	Stan. Dev.	0.039261974			
	Minimum	0.011147409			
	Maksimum	0.187717172			
	Median	0.050379			

Table III shows that the average forecasting error for LQ45 shares is 5.83915% with a standard deviation of 3.9261974%. The stock that has the lowest forecasting error is ICBP of 1.11474%, and the highest forecasting error is BUKA, with a value of 18.771717%. The last step is to perform statistical analysis, both descriptive and inferential analysis. A summary of the numerical descriptions of the two forecasting methods is made from Table I and Table III. The summary results of the numerical report of the MAPE_B and MAPE_H values are presented in Table IV.

Table IV. Results Summary of MAPE_B and Mape_H Value from LQ45 Stock Forecasting from January - February 2022

Numeric Description	MAPE_B Value	MAPE_H Value
Average	0.099145844	0.058391505
Stan. Dev.	0.104142475	0.039261974
Minimum	0.009589	0.011147409
Maximum	0.623978	0.187717172
Median	0.066705	0.050379

Table IV shows that in 4 out of 5 numerical description sizes, the MAPE value from forecasting using Holt's DES method is smaller than Brown's. The F test was carried out to test the similarity of the variances of the two forecasting methods. The results of the F test for the similarity of variance with a significance level of $\alpha = 0.05$ can be seen in Table V.

Table V. Summary of F Test Results for Equality Variance Mape_B and Mape_H Values

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	0.099145844	0.058391505
Variance	0.010845655	0.001541503
Observations	45	45
df	44	44
F	7.03576839	
P(F<=f) one-tail	9.09822E-10	
F Critical one-tail	1.650934533	

It can be seen from Table V that the calculated F value (= 7.03576839) is greater than the critical F (= 1.650934533), so it can be concluded that the variance of the two MAPE values is not the same. Because the variance is the square of the standard deviation, it can also be concluded that the standard deviation of the two MAPE values is not the same. When viewed numerically, the MAPE standard deviation with the Holt method is smaller than the standard deviation with the Brown method. To test the similarity of the paired means of the two forecasting methods, the t-test is used for paired means with different variance cases. The t-test results for paired mean with different variance cases with a significance level of $\alpha = 0.05$ can be seen in Table VI.

Table VI. Summary of T Test Results for Paired Means Case of Different Variance

	Variable 1	*Variable 2*
Mean	0.099145844	0.058391505
Variance	0.010845655	0.001541503
Observations	45	45
Hypothesized Mean Difference	0	
df	56	
t Stat	2.456372798	
P(T<=t) one-tail	0.008580539	
t Critical one-tail	1.672522304	
P(T<=t) two-tail	0.017161078	
t Critical two-tail	2.003240704	

As seen from Table VI, the calculated t value (= 2.456372798) is greater than the critical t (= 2.003240704), so it can be concluded that the average of the two MAPE values is not the same. When viewed numerically, the average MAPE using the Holt method (Variable2) is smaller than the average MAPE using the Brown method (Variable1). A visual description of the two MAPEs can be seen in the Boxplot diagram. The results of the Boxplot diagram can be seen in Figure 1 below.

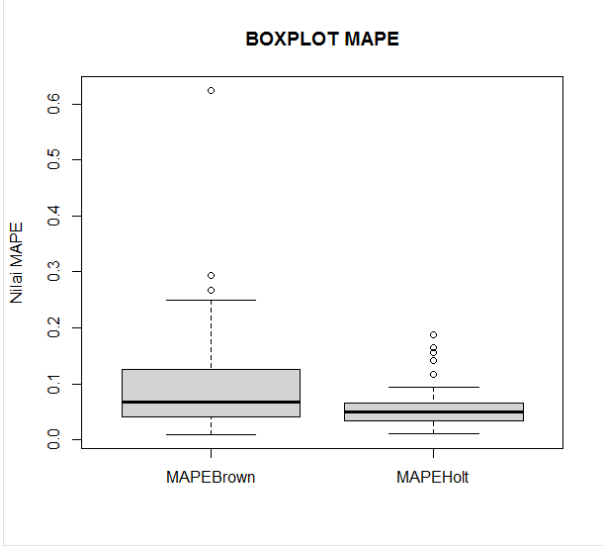

Figure 1. Boxplot Diagram for Comparison of the Distribution of MAPE Brown Method with Holt Method

The boxplot diagram in Figure 1 shows that the MAPE values for the Brown method are more spread out than the MAPE values for the Holt method. The Brown method MAPE values have three outliers, while the Holt method MAPE values have five. The median (strip center) value of Holt's MAPE method is smaller than that of Brown's MAPE method. Because the boxplot diagrams both have outliers, it can be seen that the data is not normally distributed, so it is necessary to carry out nonparametric statistical tests to confirm the results of the average similarity test.

The Wilcoxon signed exact rank test was used to test the paired means nonparametric statistically. The result is with data: data1$MAPEBrown and data1$MAPEHolt. We get V = 800 and p-value = 0.001078 for the alternative hypothesis: true location shift is not equal to 0. This p-value is smaller than the significance level of the 0.05 test, so it rejects the null hypothesis. So, it can be concluded that there is a difference in shifting accuracy based on MAPE between Brown's and Holt's DES methods. The average MAPE with the Holt method is smaller than the MAPE average with the Brown method. This supports the conclusion of the t-test for paired means with different variance cases.

The last but not least, this research also has a limitation: this research used a dataset for six years, even though during those six years, quite a lot of special events occurred and influenced stock prices, such as economic policy and the COVID-19 case and others. Another idea for these models is to shorten the dataset so that it can be used to predict online at every 1-hour interval. From a long-term perspective, users are investors; from a short-term perspective, they are traders. So, the limitation of this research is that it is not suitable for use by traders.

4 Conclusion

From this research, it can be concluded that:

1. Brown's DES method shows that the average forecasting error for LQ45 shares is 9.9146%, with a standard deviation of 10.4142%. The stock that has the lowest forecasting error is ICBP at 0.9589%, and the highest forecasting error is WSKT with a value of 62.3978%.
2. Using Holt's DES, it can be seen that the average forecasting error for LQ45 shares is 5.83915% with a standard deviation of 3.9261974%. The stock with the lowest forecasting error is ICBP, 1.11474%, and the highest is BUKA, with a value of 18.771717%.
3. The average MAPE with Holt's DES method is smaller than the MAPE average with Brown's. This is supported by the t-test for paired means with different cases of variance and also supported by the Wilcoxon signed exact rank test.
4. The standard deviation of MAPE using Holt's DES method is smaller than the standard deviation of MAPE using Brown's method. This is supported by the F test to test the variance similarity and by a Boxplot diagram.
5. Computationally, the Brown method is more accessible to apply from a programming perspective because it only depends on one parameter, namely α, while the Holt method is more challenging to apply because it depends on two parameters, namely α and β. From an investor's perspective, the DES Holt method is better used for forecasting LQ45 stocks because it has a lower average value and a lower standard deviation than the DES Brown method.

Some of the things that can be applied in this research further are:

1. Based on the results of this study, other studies can be carried out on how far the Box-Cox transformation affects the forecasting accuracy of LQ45 stocks with these two methods.
2. Future research can also examine how much of the best time-series data can be used to forecast Brown's and Holt's DES models on LQ45 stocks.

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