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COMPARING GAUSSIAN AND EPANECHNIKOV KERNEL OF NONPARAMETRIC REGRESSION IN FORECASTING INDONESIA SHARIA STOCK INDEX (ISSI)

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Abstract. *ISSI reflects the movement of sharia stock prices as a whole. It is necessary to forecast the share price to help investors determine whether the shares should be sold, bought, or retained. This study aims to predict the value of ISSI using nonparametric kernel regression. The kernel regression method is one of the nonparametric regression methods used to estimate conditional expectations using kernel functions. Kernel functions used in this study are gaussian and Epanechnikov kernel functions. The estimator used is the estimator Nadaraya-Watson. This study aims to compare the two kernel functions of nonparametric regression in predicting the value of ISSI in the period from January 2016 to October 2019. The analysis results obtained the best method in predicting ISSI values, namely nonparametric kernel regression using Nadaraya-Watson estimator and Gaussian kernel function with the MAPE value of 15% and the coefficient of determination of 85%. Independent variables that significantly affect ISSI are interest rates, exchange rates, and inflation. Curve smoothing is obtained using bandwidth value (h) searched by the Silverman rule. The calculation result with the Silverman rule obtained a bandwidth value of 101832.7431.*

Keywords: *Epanechnikov, Gaussian, Nadaraya-Watson estimator, nonparametric kernel regression, ISSI*

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1. INTRODUCTION

Investors widely choose Stocks as capital market instruments to invest in because they can provide attractive profits and pose risks [1]. A drastic drop in the stock price can put investors at risk of losses, so investors need accurate information about the stock price before investing in the capital market.

The Islamic capital market has experienced rapid growth in recent years. Indonesian people, who are majority Muslim, began to buy products sold in the Sharia capital market. Among the sharia capital market products that many investors are interested in are Sharia stocks [2]

The Indonesian Sharia Stock Index (ISSI) reflects the movement of sharia stock prices as a whole [3]. Muslim investors can refer to ISSI to determine the possibility of an increase or decrease in sharia stock prices. In the Islamic capital market, all principles and procedures of transactions are based on the teachings of the Qur'an and hadith. Islamic capital markets ideally contain several conditions, including not collecting riba and not having gharar or unclear transactions because unclear transactions are part of the gambling system.

Several external factors affect the rise and fall in stock prices, including interest rates, currency exchange rates, money supply, and inflation. To assist investors in determining the decision that the stock must be sold, bought, or maintained, it is necessary to forecast or predict the stock price. Predicting stocks can help investors avoid losses of money and time.

Some previous studies related to stock prediction and nonparametric kernel methods include research conducted by Firdaniza and Jondri using the Hidden Markov Model (HMM) and Support Vector Machine (SVM) methods to predict the ups and downs of the close price of the LQ45 Index providing prediction accuracy results with HMM of 50.98%, while with SVM of 55.56% [4].

Research conducted by [5] provided the result that the estimated relationship between the Cumulative Achievement Index (GPA) and the length of waiting time to get the work of alumni of STIA Muhammadiyah Selong public administration study program class of 2016 is more suitable using nonparametric regression with Gaussian kernel and bandwidth 0.2 due to the resulting Error Standard of 0.22. Compared to the simple linear regression method, the smallest square method results in a more significant error of 3.98.

Then research by [6] showed that modeling the growth of male toddlers using nonparametric kernel methods resulted in MSE of 1.487844 and female toddlers of 1.388796. Other research by [1] found the best methods among kernel nonparametric regression methods, ARIMA methods, and parametric regression in predicting the price of ICI (Indonesia Composite Index) are nonparametric regression kernels with MSE values of 6987.787 and bandwidth values using triangular kernel functions of 58.2.

Furthermore, research by [7] resulted in the best method between the simple linear regression method and the Nadaraya-Watson kernel nonparametric regression used to predict JII (Jakarta Islamic Index) values are nonparametric kernel regression method with MSE value of 12.840 and bandwidth value with Gaussian kernel function of 40.037. Other studies by [8] showed that the best methods between linear regression methods and nonparametric regression Nadaraya-Watson kernel used to predict ICI are Nadaraya-Watson kernel with MAPE value of 5.4% and bandwidth value with Gaussian kernel function of 305.1946.

Previous studies have shown that nonparametric kernel regression is used as a method of predicting stock value, so researchers are interested in using the kernel method with the Nadaraya-Watson estimator because it has a more flexible form, mathematical calculations are easily adjustable, and data distribution does not have to be normal. Previous research by [7] showed that Gaussian kernel functions are well utilized in predicting stock prices. Another study by [9] compared all kernel functions for economic capital calculations and showed that Epanechnikov functions provide the most efficient results. So, researchers are interested in using these two kernel functions (Gaussian kernel function and Epanechnikov kernel function) of the Nadaraya-Watson estimator in predicting the Indonesian Sharia Stock Index. The best model will be chosen.

2. RESEARCH METHODS

2.1 Research Variables

There are several research variables used in this study, namely:

a) Currency Rate

The exchange rate is the nominal price of a country's currency against another country's currency [10]. The exchange rate of a country also serves as a benchmark for the country's economic condition. The decrease in the rupiah exchange rate against the US Dollar will increase the cost of importing raw materials for production. This can result in a reduction in the profit generated by the company. Low-profit levels will cause the distribution of earnings to shareholders (dividends) to decrease so that investors are no longer interested in investing. The decrease in the Rupiah exchange rate against the US Dollar can cause a fall in the stock price. Conversely, suppose the Rupiah exchange rate strengthens. In that case, it will cause the stock price to rise because the cost of importing raw materials decreases so that the dividend distributed to shareholders will increase.

b) Money Supply

The money supply is all kinds of money in the economy. The money supply can be defined as the sum between currency and demand deposits [11]. If there is an excess amount of money in circulation, Bank Indonesia will take a policy of lowering interest rates. Falling interest rates will make investors make investments to increase the stock price. Conversely, if there is an increase in demand for money, it will raise interest rates. Rising interest rates will get investors to sell their shares. This will make the stock price fall.

c) Interest Rate

The interest rate is the cost that must be paid to borrow or rent money, a percentage agreed by both parties [12]. When Bank Indonesia decides to lower interest rates, bonds are issued at lower interest rates, so investors will increasingly hunt for stocks. When people choose many stocks to invest then the stock price will rise. Conversely, when Bank Indonesia decides to raise interest rates, bonds are issued at higher interest rates, and investors will buy and sell their shares. The number of investors who sell shares can make the stock price fall.

d) Inflation

Inflation is an event where the total price of goods increases and the value of the currency decreases [10]. If these conditions occur continuously, it will cause economic conditions to worsen overall and shake the country's political stability order. The effect of inflation on stock prices is not immediately felt on that day but will be felt when inflation impacts the business sector and the economy a moment later. If inflation in Indonesia increases continuously, then the stock price will gradually fall.

e) ISSI (Indonesia Sharia Stock Index)

ISSI is a composite index of Shariah stocks listed on the Indonesia Stock Exchange (IDX), which is an indicator of the performance of Indonesian Shariah shares. ISSI constituents are all Sharia shares listed on the IDX and included in the Sharia Securities List (DES) issued by Indonesia Financial Services Authority (OJK). This means that IDX does not conduct sharia stock selection that is entered into ISSI. ISSI constituencies are re-selected twice a year, every May and November. So that in that month, there are always Sharia stocks that come out or enter into ISSI constituencies. The calculation of ISSI value follows another method of IDX stock index, which is a weighted average of market capitalization using December 2007 as the basis of ISSI calculations.

Sharia stock is a security that has the concept of the right to share business results over a company and does not conflict with the principles of Islamic capital markets. The party issuing the shares is not allowed to carry out the following activities [2, 13]:

- Gambling and games are classified as gambling
- Trade is not offered by delivering goods or services and trade with false supply or demand.
- Ribawi financial services, among other interest-based storage institutions
- Buying and selling risks that contain elements of uncertainty (gharar)
- Trade goods or services that are illegal and morally damaging (including harm/disadvantage) following the provisions of DSN-MUI.
- Make transactions that contain elements of bribery.

The issuer must also meet the following financial ratios [2]:

- Total interest-based debt compared to total assets of no more than 45%, or
- Total interest income and other halal income compared to total business income and miscellaneous income of no more than 10%.

1.2 Data

The data used in this study are ISSI data, money supply, inflation, interest rates, and exchange rates from January 2016 to October 2019. ISSI data is sourced from the www.ojk.go.id website, inflation and interest rate data is sourced from the official website of Bank Indonesia www.bi.go.id, data on the amount of money supply and Exchange rates in the period January 2016 to October 2019 are sourced from the official website of the Ministry of Trade www.kemendag.go.id.

1.3 Data Processing

The problem-solving steps in comparing and selecting the kernel function of a nonparametric regression model to forecast ISSI are as follows:

a. Perform a correlation analysis between independent variables to dependent variables and Equations (1)
This correlation analysis is used to determine the close relationship between free and bound variables and is expressed by coefficients of correlation values (ρ). Obtain the correlation coefficient can be calculated using the Rank Spearman correlation test presented in Equation (1) [14, 15]:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \qquad (1)$$

with :

ρ = Rank Spearman correlation value
d^2 = difference of each pair
n = number of couples

The magnitude of the correlation coefficient value ranges between -1≤ρ≤1. The meaning of the ρ value is [14]

0.00 - 0.19 is a very weak correlation
0.20 - 0.39 is correlation
0.40 - 0.59 is medium correlation
0.60 - 0.79 is strong correlation
0.80 - 1.00 is a very strong correlation

b. Calculate optimum bandwidth with Equations (2)
Getting the optimal curve requires smoothing the curve using the most optimal bandwidth. The optimum bandwidth selection in this study uses Silverman's rule of thumb because research conducted in the 1990s to 2000s provides good results for multivariate kernel density estimates. The Silverman rule used is presented in Equation (2) below [16, 17] :

$$\sqrt{h} = \left(\frac{4}{d+2}\right)^{\frac{1}{d+4}} n^{\frac{-1}{d+4}} \sigma_i \qquad (2)$$

with:

σ_i = standard deviation
n = amount of data
d = amount of variable

c. Forming a model of the Nadaraya-Watson estimator equation
Kernel regression is one of the methods in nonparametric statistics used to estimate conditional expectations of random variables using kernel functions. This kernel regression will be done by smoothing the kernel using the weighted average of data. As for the kernel regression model to be presented in Equation (3) [18, 19]:

$$Y_i = m(x_i) + \varepsilon_i i = 1,2,3,\dots,n \qquad (3)$$

with:

Y_i = dependent variable

$m(x_i)$ = regression curve
ε_i = error

In kernel regression, there are several estimators, but this study used the Nadaraya-Watson estimator with the following Equations (4) [20, 21]:

$$m(x) = \frac{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right)}{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right)} \sum_{i=1}^{n} y_i \qquad (4)$$

with:

x = amount of independent variable
h = *bandwidth*
X_i = independent variable value
y_i = dependent variable value

d. Substitute Gaussian and Epanechnikov kernel function
Several kernel functions can be used in kernel density estimators. However, this study carried out calculations with two kernel functions: Gaussian kernel and Epanechnikov. The Equation of each kernel function is as follows [22, 23]:

1. Uniform: $K(u) = \frac{1}{2} I_{(-1,1)}(u)$
2. Triangular: $K(u) = (1 - |u|) I_{(-1,1)}(u)$
3. Biweight: $K(u) = \frac{15}{16}(1 - u^2) I_{(-1,1)}(u)$
4. Triweight: $K(u) = \frac{35}{32}(1 - u^2)^3 I_{(-1,1)}(u)$
5. Gaussian: $K(u) = \frac{1}{\sqrt{2\pi}} exp^{\frac{-u^2}{2}} I_{(-\infty,\infty)}(u)$
6. Epanechnikov: $K(u) = \frac{3}{4}(1 - u^2) I_{(-1,1)}(u)$

I is an indicator.

e. Perform ISSI prediction calculations using Nadaraya-Watson estimators with Gaussian and Epanechnikov kernel functions with Equations (4).

f. Compare the evaluation results of both kernel functions by calculating the coefficient of determination and MAPE values using Equations (5) and Equations (6).

The coefficient of determination describes how much an independent variable contributes to its dependent variables. Obtain the coefficient of the decision can be calculated using Equations (5) [24, 25]:

$$R^2 = \frac{JKR}{JKT} = \frac{JKR}{JKR + JKG} \qquad (5)$$

with :

$$JKR = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2$$
$$JKG = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2$$
$$JKT = JKR + JKG$$

where :

R^2 = coefficient of determination
y_i = actual data of the i-subject
$\hat{y}_i$ = subject estimates result to-i
$\bar{y}$ = average actual data

The coefficient of determination is at intervals 0 to 1. When the value of the coefficient of determination gets closer to 1, then the better the resulting model. Conversely, the resulting model is less good when the value gets closer to 0. In addition to being reviewed from the coefficient of determination, it can also be checked from the amount of MAPE value produced.

The smaller the MAPE value, the better the prediction results obtained. The Equation used in calculating MAPE is [26]:

$$MAPE = \left(\frac{1}{n} \sum_{i=1}^{n} \left|\frac{A_t - F_t}{A_t}\right|\right) \times 100\% \qquad (6)$$

where:

F_t = prediction results in the t period
A_t = actual data in the t period
n = a lot of data

There are prediction results criteria based on MAPE values [27]:

If MAPE < 10%, it produces excellent predictive capabilities
If 10% ≤ MAPE < 20%, it makes good predictive skills
If 20% ≤ MAPE ≤ 50%, it makes enough prediction ability
If MAPE > 50%, This results in poor predictive ability

g. Produces the most optimal kernel function in predicting ISSI.

3. RESULTS AND DISCUSSION

3.1 Correlation analysis

In nonparametric regression of the kernel, to find out the independent variables that affect dependent variables need to be done correlation test using Equation (1). Here are the results of the correlation test presented in Table 1:

Table 1. Correlation test

Variable	*p-value*
Exchange rate	0.010
Money supply	0.404
Interest rate	0.000
Inflation	0.007

The hypotheses used are:

H_0 : there is no relationship between the exchange rate, money supply, interest rate, or inflation against ISSI
H_1 : there is the relationship of the exchange rate, money supply, interest rate, and inflation against ISSI

Decision making on parameter testing :

If *p-value* > α (0.05) so H_0 accepted
If *p-value* < α (0.05) so H_0 rejected

Based on parameter testing, it shows that:

a) The *p-value* of the exchange rate (0.010) < α (0.05), which means H_0 is rejected, so it can be concluded that the exchange rate variable has a significant effect on ISSI. ISSI variable. When the value of the exchange rate variable increases, the value of the ISSI variable will decrease and vice versa.
b) The *p-value* of the money supply (0.404) > α (0.05), which means H_0 is accepted so that it can be concluded that the variable amount of money supply has no significant effect on ISSI.
c) The *p-value* of interest rate (0.000) < α (0.05), which means H_0 is rejected, so it can be concluded that the variable interest rate has a significant effect on ISSI. The correlation value of the interest rate variable and ISSI is -0.698, meaning that the interest rate variable has a strong relationship but leads to a negative relationship. A negative sign on the correlation value of interest rates indicates that the variable rate indirectly influences the ISSI variable. When the value of the interest rate variable increases, the value of the ISSI variable will decrease. When the interest rate variable decreases, the value of the ISSI variable will increase.
d) The *p-value* of inflation (0.007) < α (0.05), which means H_0 is rejected, so it can be concluded that the inflation variable has a significant effect on ISSI. The correlation value of the inflation variable and ISSI is 0.442, which means the inflation variable is included in the medium correlation and leads to a positive relationship. A positive sign on the correlation value of inflation indicates that the inflation variable exerts a unidirectional influence on the ISSI variable. When the value of the inflation variable increases, the value of the ISSI variable will increase. When the inflation variable decreases, the value of the ISSI variable will increase.

3.2 Optimum Bandwidth Selection

This study uses Silverman rules in equations (5) to obtain optimum bandwidth. In the previous parameter testing, the variables that affect ISSI are interest rates, inflation, and exchange rates so the optimum bandwidth obtained is:

$$\sqrt{h} = \left(\frac{4}{d+2}\right)^{\frac{1}{d+4}} n^{\frac{-1}{d+4}} \sigma_i$$

$$\sqrt{h} = \left(\frac{4}{3+2}\right)^{\frac{1}{3+4}} \times 36^{\frac{-1}{3+4}} \times (0.009352828 + 549.6750613 + 0.004448306)$$

$$h = 101832.7431$$

3.3 Formation of Kernel Nonparametric Regression Model

a. Gaussian Kernel Nonparametric Regression Model

The kernel's nonparametric regression model by substituting the Gaussian kernel function in the Nadaraya-Watson estimator equation (4) in predicting ISSI values will result in an Equation (7):

$$Y_i = m(x_i) + \varepsilon_i \, i = 1,2,3,\dots,n$$

$$= \frac{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right) y_i}{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right)} + \varepsilon_i$$

$$= \frac{\sum_{i=1}^{n} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{1}{2}\left(\frac{X_i - x}{101832,7431}\right)^2\right) y_i}{\sum_{i=1}^{n} \frac{1}{\sqrt{2\pi}} exp\left(-\frac{1}{2}\left(\frac{X_i - x}{101832,7431}\right)^2\right)} + \varepsilon_i \qquad (7)$$

with :

x = amount of independent variable
X_i = independent variable (exchange rate, interest rate, inflation)
h = *bandwidth*
y_i = value dependent variable (ISSI)

b. Epanechnikov Kernel Nonparametric Regression Model

The kernel's nonparametric regression model by substituting Epanecnikov kernel functions in the Nadaraya-Watson estimator in predicting ISSI values will result in Equations (8):

$$Y_i = m(x_i) + \varepsilon_i \, i = 1,2,3,\dots,n$$

$$= \frac{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right) y_i}{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h}\right)} + \varepsilon_i$$

$$= \frac{\sum_{i=1}^{n} \frac{3}{4}\left(1 - \left(\frac{X_i - x}{101832,7431}\right)^2\right) y_i}{\sum_{i=1}^{n} \frac{3}{4}\left(1 - \left(\frac{X_i - x}{101832,7431}\right)^2\right)} + \varepsilon_i \qquad (8)$$

with :

x = amount of independent variable
X_i = independent variable (exchange rate, interest rate, inflation)
h = bandwidth
y_i = value dependent variable (ISSI)

3.4 Comparison Result of ISSI Prediction Using Kernel's Nonparametric Regression

Using Equation 7, the results of ISSI predictions are presented in the graph plot shown in Figure 1. In the chart is displayed a comparison of prediction data and actual data:

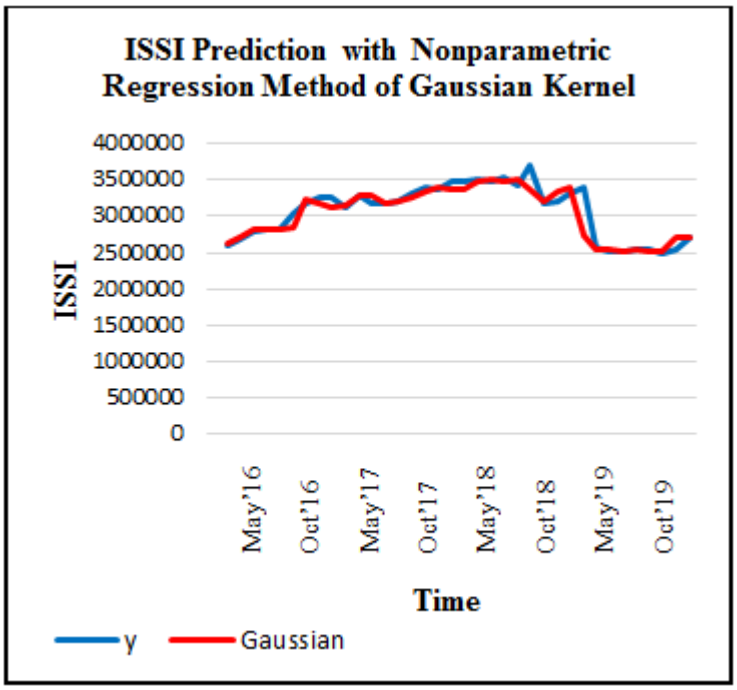

Figure 1. Actual Data and ISSI Prediction Plot using Gaussian Kernel's Nonparametric Regression

Figure 1 shows that ISSI prediction results using the Gaussian kernel's nonparametric regression method are not far from the actual data. The coefficient of determination of Gaussian kernel functions is 85%, and MAPE is 15% with good categories.

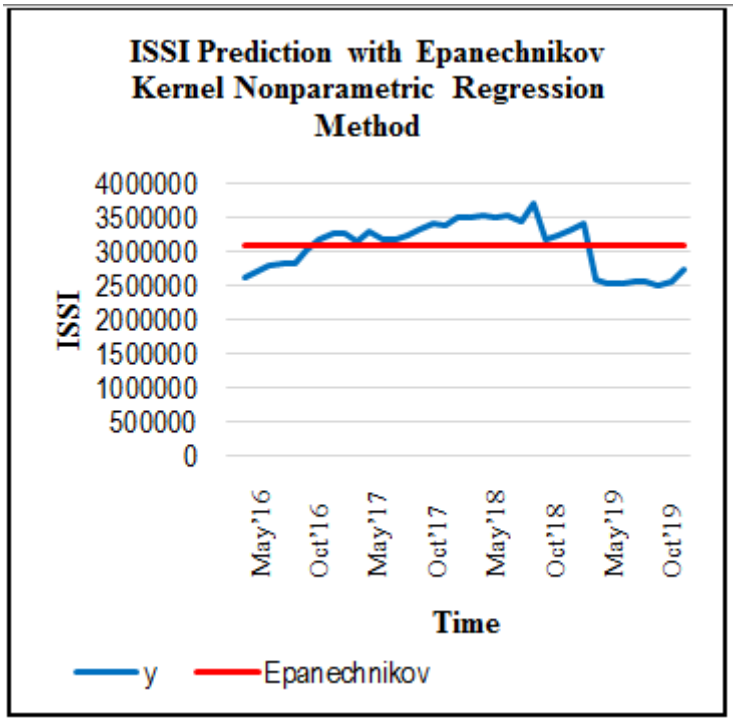

Figure 2. Actual Data and ISSI Prediction Plot using Epanechnikov Kernel's Nonparametric Regression

Based on Figure 2, the results of ISSI predictions using nonparametric regression of Epanechnikov kernels from the chart tend to be flat because the resulting value is the same. The forecasting results in a coefficient of determination of 60% and MAPE of 30%, with a good enough category.

Comparing forecasting results using nonparametric regression with Gaussian and Epanechnikov kernels can be seen from the resulting coefficients of determination and MAPE. The comparison shows that

the nonparametric regression method of Gaussian kernels is better than the nonparametric regression method of Epanechnikov kernel in predicting ISSI values.

4. CONCLUSION

Based on the results of analysis and discussion, it can be concluded that independent variables have a significant effect on ISSI, namely exchange rate variables, interest rates, and inflation. In contrast, money supply variables do not affect ISSI. Optimum bandwidth calculation using Silverman rules was obtained at 101832.7431. ISSI prediction results using Gaussian kernel functions produce a coefficient of determination of 85% and MAPE of 15%, while when using the Epanechnikov kernel function has a coefficient of determination of 60% and MAPE of 30% so that it can be concluded that the nonparametric regression method of the Gaussian kernel is better than the nonparametric regression method of the Epanechnikov kernel.

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