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Finding the Best Model in Nonlinear Regression: Using the Coefficient of Determination

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ABSTRACT

In Indonesia, inflation plays a significant role in shaping economic growth. Therefore, it is essential to examine the impact of inflation on economic growth through a comprehensive analysis. This analysis aims to identify the factors influencing economic growth in Indonesia by utilizing nonlinear regression analysis. The study focuses specifically on modeling economic growth in Batam City and its correlation with inflation. The primary goal is to identify the most effective nonlinear regression model that accurately represents the relationship between economic growth and inflation, as determined by the coefficient of determination. The method used in this research is nonlinear regression methods provide a more accurate and comprehensive analysis when dealing with complex relationships and can help uncover valuable insights that may be missed by simpler linear models. The results of the analysis finding the model that is suitable for modeling inflation on economic growth is a quadratic model with a coefficient of determination of 73.4%. The research has found that the best model for explaining the impact of inflation on economic growth is the Quadratic model with an R-value of 0.734 or 75%. These results indicate that the Quadratic model can account for 75% of the influence of inflation on economic growth.

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A. INTRODUCTION

During the current COVID-19 pandemic, the economic development of an area is a regional economic development planning process that is carried out in stages by local governments and communities in managing and allocating existing resources in an area such as Natural Resources (SDA), Human Resources. (HR), Investment and Institutional Resources and other resources to stimulate development both in terms of quantity and quality of economic activity in a region (Khoiri et al., 2020). Several factors influencing economic development are PDRB, unemployment rate, IPM and economic growth (Purba et al., 2019). Economic growth is an activity in the economy that has an impact on increasing goods and services produced by the community and the prosperity of the community will increase in the long term from economic development (Yuniarti et al., 2020). There are many factors that

are considered to have an effect on economic growth, some of which are inflation and the Consumer Price Index (CPI). Based on data released by Bank Indonesia, the CPI in July 2022 experienced an increase compared to the previous month of 4.35%, mainly originating from administered prices inflation, in the midst of maintained low core inflation and volatile foods which began to decline. Inflation is one of the main concerns for countries in the world today, inflation is at the root of economic dynamics that risks hampering the pace of economic recovery due to the impact of the Covid-19 pandemic, according to the market monitoring system and basic needs, the Ministry of Trade's Consumer Price Index in Indonesia is estimated increased by 23.73%. Inflation that occurred in March 2022 was driven by increasing inflationary pressures in all regions, Sumatra was one of the provinces experiencing the highest inflation (IHK, 2022) as shown in Figure 1.

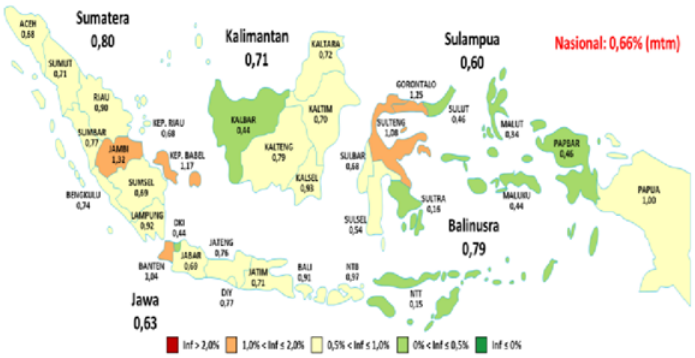

Figure 1. Inflation Map

Based on research conducted (Widiaty and Nugroho, 2020), the variables that affect economic growth are inflation and foreign debt, inflation that rises within a certain limit can be used as a parameter in assessing an economy. Research conducted (Palindangan and Bakar, 2021), economic growth is not influenced by the unemployment rate. Meanwhile, the research conducted by (Woestho et al., 2021), shows that the regional share and differential shift components have a significant influence on economic growth in certain regions. In addition, poverty reduction can occur due to economic growth and the growth of the financial sector which has increased every year (Ginting and Dewi, 2013). Based on the above description, inflation has a perspective on economic growth in Indonesia. For this reason, a review of inflation will be carried out on economic growth (Widiaty and Nugroho, 2020). The analysis was carried out to determine the factors that influence economic growth in Indonesia using regression analysis, significantly there are several influencing factors such as exports, tax revenues and exchange rates (Yuniarti et al., 2020). In this study, we will utilize nonlinear regression analysis to explore the connection between the economic growth observed in Batam City and the corresponding inflation. Our objective is to identify the most suitable nonlinear regression model that effectively characterizes the relationship between economic growth and inflation, as indicated by the coefficient of determination.

Meta regression analysis reveals that education positively influences economic growth, as evidenced by its significant impact across various influencing factors (Benos and Zotou, 2014). The impact of wealth on long-term economic growth and natural resources has been examined using the Meta Analysis approach, revealing that certain aspects of the study design are particularly effective in explaining the observed variations (Havranek et al., 2016). (Haseeb et al., 2019) Extensive literature exists on supply chain performance (SCP), which is influenced by both regulatory constraints and a company's diverse motivations. Additionally, the analysis indicates that SCP is affected by investment growth rate and population growth rate. On (Kala et al., 2018), Research conducted using the Cobb-Douglas Production Function and the ordinary least square method (OLS) indicates that controlling inflation can lead to a reduction in interest rates, thereby increasing capital accumulation and ultimately fostering economic growth in Indonesia. On the (Yolanda, 2017), Multiple regression analysis was employed to discover various models in the data analysis. The findings, particularly from model 1, suggest that BI Rate, Foreign Exchange Rates, Money Supply, oil price, and gold prices significantly influence the inflation level in Indonesia when considered together.

Conversely previous studies that utilized a single method to model economic growth, this research aims to enhance the analysis by incorporating multiple models and implementing nonlinear regression analysis. The study seeks to explore a range of model options, including linear, logarithmic, quadratic, and exponential models, to determine the most appropriate one for representing economic growth. This comparison of methods enables us to assess and comprehend the extent to which each model reflects the relationship between the variables under study. By doing so, we can identify the model that provides the most accurate and reliable

description of the data. Ensuring the model's reliability is crucial in obtaining dependable results.

B. RESEARCH METHOD

1. Descriptive Statistics

Descriptive statistics are part of statistics that play a role in data collection, presentation, and interpretation of data both in graphic and descriptive form, so that the data presented can be easily understood or read (Handayani et al., 2023). Descriptive statistics serves to describe the object under study through sample data or the population that is the object of a research conducted (Haridanti et al., 2018).

2. Nonlinear Regression Analysis

Regression analysis is a statistical method used to determine the pattern of the relationship between the dependent variable and the independent variable (Arkes, 2019). Based on the pattern of relationships represented, the regression analysis is divided into two, namely, linear regression analysis and nonlinear regression analysis. Nonlinear regression analysis that is often used to model several types of data is the Log-logistic model, the Weibull model, the Gompert model and the logistics model (Pradani et al., 2021). In addition, in nonlinear regression there are several models that can be used such as exponential models, logarithmic models, and quadratic models. The nonlinear relationship of changes in the dependent variable is followed by a variable change in the independent variable within the specified region. In general, the nonlinear regression model can be us equation 1,

$$y_i = f(x_i, \theta) + \varepsilon_i \tag{1}$$

Information: y_i = observation value of dependent variabel. x_i = observation value of independent variabel. θ = predicted parameter vector. ε_i = error value.

The function f is a regression function that must be estimated and is a nonlinear function in the parameter θ. However, the regression model is the same as the linear regression model except that y_i is a nonlinear function of the observed parameters, but in a nonlinear regression model there is at least one derivative of a function that corresponds to one of the observed parameters. To distinguish the difference between linear and nonlinear models, an estimator of the value in nonlinear regression is used. The exponential regression model can be us equation 2,

$$y_i = \theta_0 e^{\theta_1 x_i} + \varepsilon_i \tag{2}$$

Information: y_i = observation value of dependent variabel. x_i = observation value of independent variabel. θ_0, θ_1 = predicted parameter vector. ε_i = error value.

The quadratic model is the value of the dependent variable with a linear up or down linear form so as to form a parabolic curve (Utami et al., 2021). The general equation for the quadratic model can be us equation 3,

$$\hat{Y} = a + bX + cX^2 \tag{3}$$

Information: $\hat{Y}$ = Dependent variable. X = Independent Variable. a, b, c = Constant (intercept).

3. Correlation (r), Coefficient Determination (R^2)

Correlation is a certain value that serves to determine the relationship between the dependent variable and the observed independent variable (Utami et al., 2021). The relationship between variables is said to be strongly correlated when it has a correlation value of $-1 < r < 1$. The value of r towards -1 indicates a negative relationship between the observed variables. While the value of r towards 1 indicates a positive relationship between the observed variables.

The coefficient of determination (R^2) is a value that is able to explain how much (percentage) the relationship can be explained by the independent variable to the dependent variable (Musfiroh et al., 2018). Meanwhile, the mean square error (MSE) is a value that characterizes the level of error in the estimation results for the estimation of the model or forecasting carried out. The smaller the MSE value in an estimation, the results obtained are considered better (Kurniasih et al., 2013).

The data used in this study is secondary data sourced from the (BPS, 2022) report. The secondary data consists of information related to economic growth and inflation in Batam City for the year 2021. The data used in the study was obtained from the (BPS, 2022) report and focuses on economic growth and inflation in Batam City during 2021, Table 1 data used:

Table 1. Economic Growth and Inflation in Batam City in 2021

Economic Growth	Inflation
365	2,4
614	29,8
385	3,3
286	3,3
397	0,7
764	12,9
427	6,5
153	1,1
231	1
524	11,4
328	5,5
240	2,8

(Jones, 2019) To find out a suitable nonlinear model to determine the relationship that can be explained by the independent variable, namely inflation to the dependent variable, namely economic growth.

The methods used in this research are as follows:

1. Describe the data
2. Identifying correlations between observed variables
3. Perform nonlinear regression analysis with exponential models, logarithmic models, and quadratic models
4. Comparing the value of R^2 and MSE on the modelling results using the exponential model, logarithmic model, and quadratic model.
5. Determine the best model to use
6. Interpret the results obtained to determine the relationship between inflation and economic growth that can be represented.

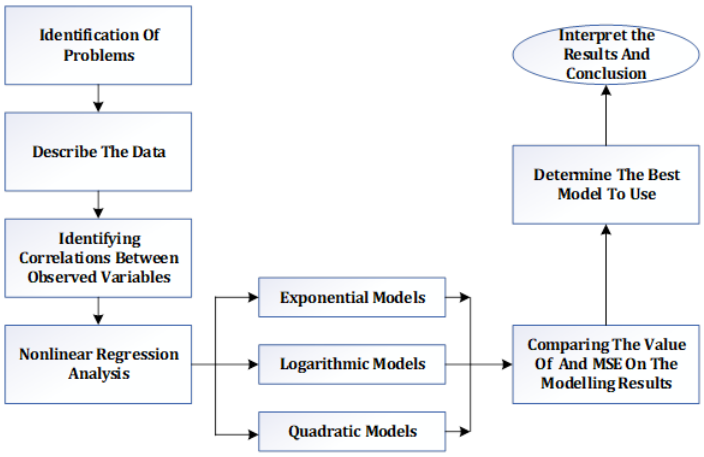

Figure 2. Research Flowchart

C. RESULTS AND DISCUSSION

1. Description of Data and Identification of Correlation

Table 2. Variable Processing Summary

		Variables	
		Dependent	Independent
		Economic Growth	Inflation
Number of Positive Values		12	12
Number of Zeros		0	0
Number of Negative Values		0	0
Number of Missing Values	User-Missing	0	0
	System-Missing	0	0

The analysis presented in Table 2 reveals that the data observations are related to specific variables. These observations pertain to inflation data, which serves as the independent variable, and economic growth, which is the dependent variable. This data was collected and analyzed over a one-year period to establish their relationships and patterns.

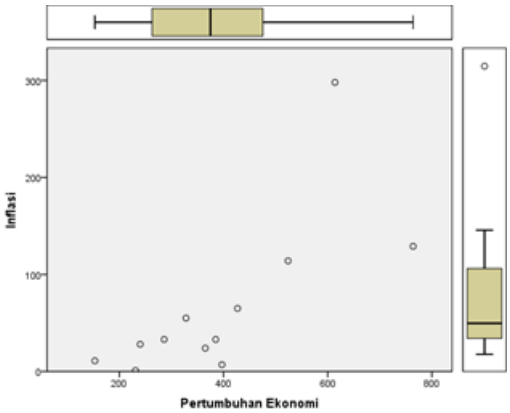

Figure 3. Plot of the relationship of inflation to economic growth

Based on the plot from figure 3, it can be seen that there is a linear relationship between inflation and economic growth. This allows us to carry out further analysis. Furthermore, correlation analysis was conducted to determine the relationship between inflation and economic growth. The following are the results of the analysis carried out using statistical software: Based on the plot above, it can be seen that there is a linear relationship between inflation and economic growth. This allows us to carry out further analysis. Furthermore, correlation analysis was conducted to determine the relationship between inflation and economic growth. Table 3 are the results of the analysis carried out using statistical software:

Table 3. Pearson Correlations

		Inflation	**Economic growth**
Inflation	Pearson Correlation	1	.732**
	Sig. (2-tailed)		0.007
	N	12	12
Economic growth	Pearson Correlation	.732**	1
	Sig. (2-tailed)	0.007	
	N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Based on the results of the correlation analysis conducted using the Pearson correlation coefficient, it can be seen that there is a relatively large positive correlation. This can be seen from the correlation value between inflation and economic growth of 0.732. That is, there is a positive relationship that occurs between the observed variables, namely inflation on economic growth.

2. Nonlinear Regression Analysis

To model the relationship between inflation and economic growth, a nonlinear regression analysis was performed. The primary objective of this analysis was to identify the most appropriate model for describing this relationship. Table 4 contains the results and details of the nonlinear regression analysis conducted to establish the fitting model for inflation and economic growth.

Table 4. Model Description

Model Name		MOD_7
Dependent Variable	1	Economic growth
Equation	1	Linear
	2	Logarithmic
	3	Quadratic
	4	Exponentiala
Independent Variable		Inflation
Constant		Included
Variable Whose Values Label Observations in Plots		Unspecified
Tolerance for Entering Terms in Equations		0.0001

a. The model requires all non-missing values to be positive.

The analysis results in Table 4 reveal that the modeling of the relationship between inflation and economic growth involves three nonlinear models. These models include the logarithmic, quadratic, and exponential models, and they are being considered for comparison with a linear model. Based on the analysis, the study explores and contrasts the performance of these various models in describing the relationship between inflation and economic growth.

Linear Models

Table 5. Model Summary for Linear Models

R	R Square	Adusted R Square	Std. Error of the Estimate
0.732	0.535	0.489	123.544

The summary model obtained from Table 5 using a linear model, the correlation results that can be represented by inflation on economic growth are 0.732, which means that the two variables observed are linearly correlated with each other. Meanwhile, the R-Square value is 0.535. This means that 53.5% of inflation is able to explain the relationship to economic growth, the remaining 46.7% is explained by other variables outside of the observed variables.

Table 6. Result Analysis of Variance for Linear Models

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	175958.226	1	175958.226	11.528	0.007
Residual	152631.441	10	15263.144		
Sum	328589.667	11			

Furthermore, the analysis of variance results in Table 6 provides insights into the impact of inflation on economic growth. This impact is signified by the significance level (sig.) obtained, which is 0.007, falling below the predetermined alpha (α) value of 5% (0.005). The significance of 0.007 suggests a statistically significant effect of inflation on economic growth, as revealed by the analysis of variance in Table 6.

Table 7. Result of Coefficients for Linear Models

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Inflation	1.518	0.447	0.732	3.395	0.007
(Constant)	291.868	46.435		6.286	

Table 7 displays the regression model, which represents the relationship between the variables. The regression model obtained in the linear form is expressed as $Y = 291.868 + 1.518$ Inflasi. This model describes how the dependent variable Y is influenced by the independent variable Inflasi in a linear fashion, as shown in Table 7.

Logarithmic Models

Table 8. Model Summary for Logarithmic Models

R	R Square	Adusted R Square	Std. Error of the Estimate
0.700	.490	.439	129.433

Based on the results of the summary model Table 8, using the logarithmic model, the correlation results that can be represented by inflation on economic growth are 0.7, which means that the two variables observed are linearly correlated with each other. Meanwhile, the R-Square value is 0.49. That is, 49% of inflation is able to explain the relationship to economic growth, the remaining 51% is explained by other variables outside of the observed variables.

Table 9. Result Analysis of Variance for Linear Models

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	161061.867	1	161061	9.614	0.011
Residual	167527.799	10	16752.78		
Sum	328589.667	11			

The analysis of variance results in Table 9 highlights the impact of inflation on economic growth. This impact is evident in the significance level (sig.) obtained, which is 0.01, falling below the predefined alpha (α) value of 5% (0.005). The significance level of 0.01 suggests that there is a statistically significant effect of inflation on economic growth, as revealed by the analysis in Table 9.

Table 10. Result of Coefficients for Linear Models

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Inflation	80.442	25.944	0.700	3.101	.011
(Constant)	115.831	96.835		1.196	.259

The regression model is presented in Table 10, depicting the relationship between the variables. In the linear model, the regression equation obtained is $Y = 115.831 + 80.442$ Inflasi. This linear model showcases how the dependent variable Y is influenced by the independent variable Inflasi, as indicated in Table 10.

Quadratic Models

Table 11. Model Summary for Quadratic Models

R	R Square	Adusted R Square	Std. Error of the Estimate
.857	.734	.675	198.590

Based on the results of the summary model from table 11 using the quadratic model, the correlation results that can be represented by inflation to economic growth are 0.857, which means that linearly the two variables observed have a greater correlation with each other than the previous model. Meanwhile, the R-Square value is 0.734. This means that 73.4% of inflation is able to explain the relationship to economic growth, the remaining 26.6% is explained by other variables outside of the observed variables.

Table 12. Result Analysis of Variance for Linear Models

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	241110.130	2	120555.065	12.403	0.003
Residual	87479.537	9	9719.949		
Sum	328589.667	11	11		

The analysis of variance results in Table 12 demonstrates a significant impact of inflation on economic growth. This influence is evident through the significance level (sig.) obtained, which stands at 0.003, falling below the designated alpha (α) threshold of 5% (0.005). The significance level of 0.003 points to a statistically significant relationship between inflation and economic growth, as indicated by the analysis in Table 12.

Table 13. Result of Coefficients for Linear Models

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Inflation	4.514	1.211	2.176	3.728	.005
Inflation**2	-.010	.004	-1.511	-2.589	.029
(Constant)	204.538	50.109		14.082	.003

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Table 13 provides the regression model, offering insight into the relationship between variables. In the linear model, the obtained regression equation is expressed as $Y = 204.538 + 4.514^{-0.01}$ Inflasi. This linear model illustrates how the dependent variable Y is influenced by the independent variable Inflasi, as revealed in Table 13.

Exponential Models

Table 14. Model Summary for Quadratic Models

R	R Square	Adusted R Square	Std. Error of the Estimate
.857	.470	.418	.341

Based on the results of the summary model from table 14 using the exponential model, the correlation results that can be represented by inflation to economic growth are 0.686, which means that the two variables observed are linearly correlated with each other. Meanwhile, the R-Square value is 0.47. This means that 47% of inflation is able to explain the relationship to economic growth, the remaining 53% is explained by other variables outside of the observed variables.

Table 15. Result Analysis of Variance for Linear Models

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1.031	1	1.031	8.8853	0.014
Residual	1.160	10	9.116		
Sum	2.191	11	11		

The analysis of variance results in Table 15 indicate a discernible impact of inflation on economic growth. This influence becomes evident through the significance level (sig.) obtained, which stands at 0.014, falling below the predetermined alpha (α) threshold of 5% (0.005). The significance level of 0.014 highlights a statistically significant connection between inflation and economic growth, as demonstrated in the analysis in Table 15.

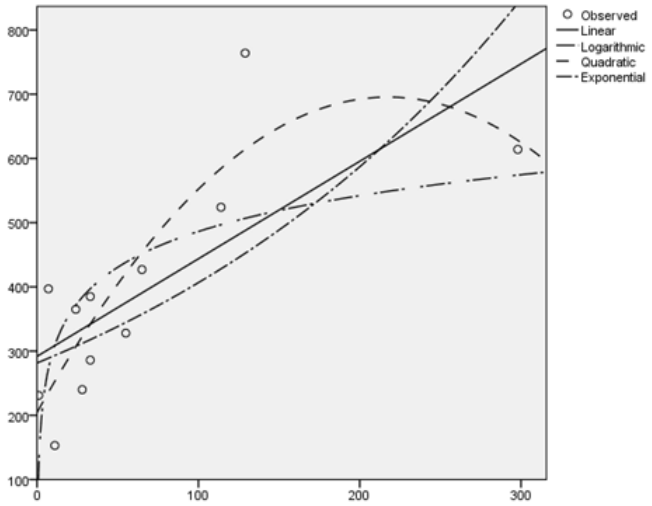

Figure 4. Comparison plot of the relationship between inflation and economic growth with the modeling

The graphical representation, presented in the plot, serves as a visual tool for understanding economic trends. By offering a visual medium, the plot facilitates a direct comparison between the trajectories of inflation and economic growth. The basis for this comparison lies in the modeling exercises that have been conducted, providing a solid analytical foundation. Through the plotted data, one can easily discern and analyze the relationship between inflation rates and economic growth patterns. The modeling process underpinning this comparison ensures a comprehensive and insightful exploration of the dynamics between inflation and economic growth.

The plot provides a graphical representation. It allows for a visual comparison between inflation and economic growth. This comparison is based on the conducted modeling.

3. Determining the Best Model

Table 16. Model Summary and Parameter Estimation for Determining the Best Models

Equation	Parameter Estimates					Parameter Estimates		
	R Square	F	Df1	Df2	Sig.	Constant	B1	B2
Linear	0.535	11.528	1	10	0.007	291.868	1.518	
Logarithmic	0.49	9.614	1	10	0.011	115.831	80.442	
Quadratic	0.734	12.403	2	9	0.003	204.538	4.514	-0.01
Exponential	0.47	8.885	1	10	0.014	281.561	0.004	

Based on the results of the analysis carried out, table 16 can be seen that the comparison of each model is built to model the relationship that can be explained by inflation to economic growth, where in previous studies only carried out modeling with one method in determining the best model. To determine the best model to choose, we need to compare the highest coefficient of determination (R-Square) and the minimum error value. In (Van Leeuwen et al., 2018), using linear quadratic for stratified by tumour site and by tumour histology. The result finding best model can be used Quadratic model with an R value of 0.734 or 75% model is able to explain the effect of inflation on economic growth. In previous studies there were dosnt comparison of several models to get the best model between inflation and economic growth. The research has found that the best model for explaining the impact of inflation on economic growth is the Quadratic model with an R-value of 0.734 or 75%. These results indicate that the Quadratic model can account for 75% of the influence of inflation on economic growth, (Archontoulis and Miguez, 2015) The research carried out only uses a linear model to model Applications in Agricultural Research.

D. CONCLUSION AND SUGGESTION

Based on the results of the analysis, it can be concluded that there is a positive relationship between inflation and economic growth that occurs. Comparison of three methods to get the best model by implementing non-linear regression analysis to determine the effect of inflation on economic growth. In addition, based on the comparison of the summary model above using the quadratic model, the correlation results that can be represented by inflation on economic growth are 0.857, which means that linearly the two variables observed have a greater correlation with each other than the previous model. Meanwhile, the R-Square value is 0.734. This means that 73.4% of inflation is able to explain the relationship to economic growth, the remaining 26.6% is explained by other variables outside of the observed variables. Based on the results obtained, it is necessary to review other factors that affect economic growth.

DECLARATIONS

AUTHOR CONTIBUTION

All authors contributed to the writing of this article.

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COMPETING INTEREST

The authors declare no conflict of interest in this article.

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