Causality Analysis Between Gross Domestic Product and Foreign Direct Investment

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Abstract

This paper investigates the relationship between Gross Domestic Product (GDP) and Foreign Direct Investment (FDI) to determine which economic indicators have a more significant impact on the other. The paper employs a linear regression analysis approach to examine the causality between GDP and FDI in Malaysia dataset. This paper seeks to understand whether GDP influences FDI or whether FDI is a significant determinant of GDP growth in Malaysia. The linear regression was coded using Scilab programming. Findings suggest no or very weakly causal relationship between GDP and FDI. This finding implies that policies promoting FDI might not or weakly stimulate GDP growth, and vice versa. The FDI influence on GDP is stronger than the influence of GDP on FDI. These findings have implications for policymakers and economists seeking to optimize economic growth strategies. Finally, a complete Scilab coding is given to ensure that the readers can implement the proposed method.

Keywords: Gross Domestic Product (GDP), Foreign Direct Investment (FDI), Linear Regression Analysis, Bidirectional Causality, Economic Growth

Introduction

Gross Domestic Product (GDP) and Foreign Direct Investment (FDI) are two critical indicators of economic performance and growth (Carlos & Eddie 2015; Wang et al. 2021). GDP represents the total value of goods and services produced within a country's borders over a specific period, serving as a broad measure of a nation's overall economic activity. FDI, on the other hand, refers to investments made by foreign entities in domestic businesses or assets, which can include the establishment of new operations, acquisitions, or mergers.

The relationship between GDP and FDI (Wang et al. 2021) has been the subject of extensive research, with economists and policymakers debating whether GDP growth drives FDI inflows or if FDI is a key driver of GDP growth. Understanding this relationship is essential for crafting policies that foster sustainable economic development. This paper aims to contribute to this ongoing debate by employing linear regression analysis to explore the causality between GDP and FDI.

Literature Review

The relationship between GDP and FDI has been explored in numerous studies, with varying conclusions. Some studies suggest that GDP growth attracts FDI, as investors are more likely to invest in countries with strong economic performance and growth prospects. For instance, studies by Alfaro et al. (2004) and Borensztein et al. (1998) indicate that countries with higher GDP growth rates tend to attract more FDI due to the promise of higher returns on investment.

Conversely, other studies argue that FDI is a significant driver of GDP growth (Carlos & Eddie 2015). Study by Mohamed et al (2013) found that no causality was found to exist between FDI and economic growth. According to De Mello (1999) and Agosin and Mayer (2000), FDI contributes to economic growth by providing capital, technology transfer, and managerial expertise, which can enhance productivity and innovation in the host country. These studies suggest that FDI can lead to an increase in GDP by boosting domestic investment and employment. While according to Sijabat (2023), FDI and GDP have both been proven to be causative in the ten ASEAN nations studied. The causal association between FDI and GPI is two-way in the short run.

The application of linear regression in literature thus bridges the gap between traditional literary criticism and data-driven approaches, providing a robust framework for exploring complex textual phenomena (Jockers, 2013). This method's utility in both theoretical and applied literary research highlights its versatility and enduring relevance in the field. Linear regression also a powerful tool in machine learning. The method have been use comprehensively in machine learning to relates between one or more predictors (Maulud & Abdulazeez 2020). The method also applied in many other computer science researches (Huang, 2020). Ali Rehman et al (2024) apply multiple regression to estimate soil loss erodibility in Peninsular Malaysia. This research shows the contribution of regression to predict natural hazards.

Methodology

To explore the relationship between GDP and FDI, this study employs a linear regression analysis approach. Linear regression is a statistical method used to examine the relationship between a dependent variable and one or more independent variables. In this case, the analysis will focus on determining whether GDP can be predicted by FDI (GDP as the dependent variable and FDI as the independent variable) and vice versa.

a. Data Collection

The data used in this study is collected from reliable sources, i.e. Department of Statistic, Malaysia (DOSM). The GDP, measured in RM100 billion, showed a consistent upward trajectory, reflecting the country's economic growth. This growth was driven by various sectors, such as manufacturing, services, and exports, which contributed significantly to the overall economic expansion.

Foreign Direct Investment (FDI), measured in RM10 billion, also played a crucial role in Malaysia's economic landscape. Despite fluctuations, FDI inflows generally supported the country's development. The dataset includes annual GDP and FDI figures for a sample of countries over a period of 12 years (2009-2020). The selected countries represent different regions and levels of economic development, ensuring a comprehensive analysis.

b. Model Specification

The study employs two linear regression models (Hastie et al., 2009). to examine the relationship between GDP and FDI:

1. Model 1: GDP as the dependent variable and FDI as the independent variable.

$$GDP_t = B_0 + B_1 FDI_t + \varepsilon_t$$

Where:

GDP_t represents the Gross Domestic Product at time t.

FDI_t represents the Foreign Direct Investment at time t.

B_0 is the intercept term.

B is the coefficient of FDI, indicating the impact of FDI on GDP.

ε_t is the error term.

2. Model 2: FDI as the dependent variable and GDP as the independent variable.

$$FDI_t = B_0 + B_1 GDP_t + \varepsilon_t$$

Where,

FDI_t represents the Foreign Direct Investment at time t.

GDP_t represents the Gross Domestic Product at time t.

B_0 is the intercept term.

B_1 is the coefficient of GDP, indicating the impact of GDP on FDI.

ε_t is the error term.

Data Analysis Methodology

In this paper, we analyze the dataset thoroughly by executing six steps as follows.

1. Descriptive Statistics: Descriptive statistics, such as mean, median, standard deviation, and correlation coefficients, are calculated for both GDP and FDI to provide an overview of the data.

2. Linear Regression Analysis: The linear regression models specified above are estimated using the Ordinary Least Squares (OLS) method. The regression coefficients B_0 and $B_1$are analyzed to determine the strength and direction of the relationship between GDP and FDI.

3. Hypothesis Testing: The significance of the regression coefficients is tested using t-tests, and the overall model fit is assessed using the F-test.

4. Accuracy Test: The accuracy of both models tested using Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) measurement.

5. Interpretation of Results: The results of the linear regression analysis are interpreted to determine whether GDP or FDI has a more significant impact on the other.

Model Construction and Analysis

We start with executing the descriptive statistics to the dataset.

The descriptive statistics for GDP and FDI across the sample countries are presented in Table 1.

Table 1: Descriptive Statistics for GDP and FDI

Variable	Mean	Median	Standard Deviation	Correlation
GDP	10.862500	10.9465	2.5454365	0.348234
FDI	3.1543583	3.3982	1.1575468	

The mean and median values for both GDP and FDI are close to each other indicates both factors are almost normal distributed. The deviation value, which is standard deviation shows that GDP distribution disperse almost twice than FDI distribution. These two factors corelate positively to each other by 0.348234 which shows is weak relationship. The value indicates that the correlation between GDP and FDI not so moderate. From this value the coefficient of determination can be calculated as 0.1213. This means that only 12.13% of the variance in GDP is explained by FDI or vice versa.

The correlation coefficient between GDP and FDI suggests a weak positive relationship, indicating that as GDP increases, FDI also tends to increase, and vice versa. However, correlation does not imply causation, necessitating further analysis through linear regression.

Detecting Outliers using Z-Score

Z-score formula:

$$Z = \frac{x - \mu}{\sigma}$$

Where:

- x is the data point,
- μ is the mean of the dataset,
- σ is the standard deviation of the dataset.

Steps for Z-score outlier detection:

1. Compute the mean (μ) and standard deviation (σ) for the data.
2. Calculate the Z-score for each data point.
3. Typically, if $| Z | > 3$, the data point is considered an outlier.

For GDP data:

1. Calculate the mean and standard deviation:
   - Mean (μ_{GDP}): $\frac{6.299 + 8.214 + \cdots + 13.439}{12} = 10.985$
   - Standard deviation (σ_{GDP}), $\sigma = 2.399$ (calculated from the data)
2. Calculate the Z-scores for each data point:

$$Z_{GDP} = \frac{(GDP - 10.985)}{2.399}$$

Using this formula, we transform all GDP data into Z-scores:
$[-1.95, -1.15, -0.97, -0.78, -0.60, -0.36, 0.33, 0.55, 0.84, 1.11, 1.36, 1.02]$

No Z-scores exceed 3 or -3, so there are no outliers in the GDP data using Z-score.

For FDI data:

1. Calculate the mean and standard deviation:
   - Mean $(\mu FDI) = \frac{0.512 + 2.918 + \cdots + 1.4639}{12} = 3.112$
   - Standard deviation $(\sigma FDI), \sigma = 1.108$ (calculated from the data)
2. Calculate the Z-scores for each data point:

$$Z_{FDI} = \frac{(FDI - 3.112)}{1.108}$$

Using this transformation formula to FDI data, yields Z-scores:
$[-2.34, -0.18, 0.56, -0.23, 0.64, 0.40, 0.75, 1.44, 0.84, -0.03, 0.11, -1.49]$

No Z-scores exceed 3 or -3, so there are no outliers in the FDI data using Z-score.

Therefore this dataset is clean.

To analyze the causation between GDP and FDI, we construct two models, GDP dan FDI Models. In this paper, the GDP model is a linear model that analyze the impact of FDI towards GDP. While, FDI model is a linear model that analyze the impact of GDP towards FDI. In this subtopic, we construct and analyzed the Linear regression model in two subtopics, i.e. GDP model dan FDI model. In both subtopic we execute linear regression analysis, hypothesis testing and accuracy test.

GDP Model: Impact of FDI on GDP

A linear Least square formulation can be illustrated as follows. Suppose we have a set of four GDP and FDI data. A set of relation for GDI and FDI data can be written as Eq. (1).

$$\left.\begin{array}{c} B_0 + B_1 FDI_1 = GDP_1 \\ B_0 + B_1 FDI_2 = GDP_2 \\ B_0 + B_1 FDI_3 = GDP_3 \\ B_0 + B_1 FDI_4 = GDP_4 \end{array}\right\} \text{ Eq. (1).}$$

We can rewrite Eq. (1) in metrics form as in Eq. (2).

$$\left.\begin{bmatrix} 1 & FDI_1 \\ 1 & FDI_2 \\ 1 & FDI_3 \\ 1 & FDI_4 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \end{bmatrix} = \begin{bmatrix} GDP_1 \\ GDP_2 \\ GDP_3 \\ GDP_4 \end{bmatrix}\right\} \text{ Eq. (2)}$$

Eq. (2) can be rewritten in simpler form as Eq. (3).

$$AB = y \text{ Eq. (3)}$$

Where

$$A = \begin{bmatrix} 1 & FDI_1 \\ 1 & FDI_2 \\ 1 & FDI_3 \\ 1 & FDI_4 \end{bmatrix}, B = \begin{bmatrix} B_0 \\ B_1 \end{bmatrix}, y = \begin{bmatrix} GDP_1 \\ GDP_2 \\ GDP_3 \\ GDP_4 \end{bmatrix}$$

To find the value of vector B, we have to derived as follows.

$$AB = y$$

$$A^T AB = A^T y$$

$$(A^T A)^{-1} A^T AB = (A^T A)^{-1} A^T y$$

$$B = (A^T A)^{-1} A^T y \text{ Eq. (4)}$$

We program Eq. (4) using Scilab programming. The results of the linear regression analysis for GDP model are presented in Table 2 and Table 3.

Table 2: Linear Regression Results for GDP model (GDP as the Dependent Variable)

Variable	B_1	Standard Error	t-Statistic	p-Value
FDI	0.765659	0.651781	1.174744	0.267312
Constant	8.4473371	2.179154	3.876291	0.003077

Table 2: ANOVA Table

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	8.640904	8.640904	1.380024	0.267312
Residual	10	62.61417	6.261417		
Total	11	71.25507			

The regression coefficient for FDI (B_1) is weakly positive at the 5% level, suggesting that FDI has a very weakly positive impact on GDP. This claim supports the alternative hypothesis that FDI contributes to economic growth by providing capital, technology, and managerial expertise. Therefore, the linear regression model gathered, namely GDP model is given by

$$GDP = 8.4473371 + 0.765659FDI + \varepsilon_t$$

Furthermore, we conduct hypothesis testing to analyze the significance of the B_1 value gathered in GDP model. We set the hypothesis statement as below.

Null Hypothesis, H_0: FDI does not have a significant impact on GDP ($B_1 = 0$).

Alternative Hypothesis, H_1: FDI has a significant impact on GDP ($B_1 \neq 0$)).

Since from Table 2, p-value $(0.267312) > \alpha(0.05)$, we do reject H_o. Therefore, we conclude that FDI has a no significant impact on GDP or we have not enough evidence to conclude that FDI have significance impact on GDP. This may be cause of the small amount of observed data. Using the GDP model, predicted values can be gathered and compared to observed data as given in Figure 2.

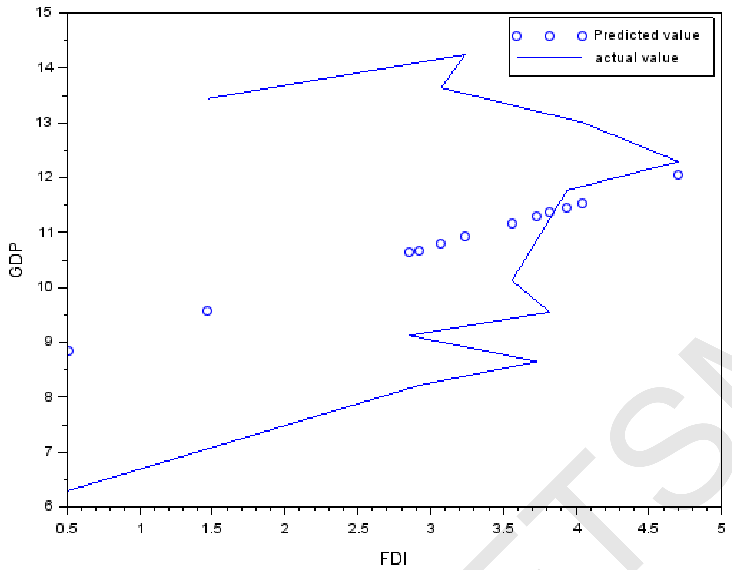

Figure 2: The Observed data vs Predicted values using GDP model.

The equation $GDP = 8.4473371 + 0.765659FDI$ is a linear regression model that expresses the relationship between Gross Domestic Product (GDP) and Foreign Direct Investment (FDI). This type of equation is commonly used in econometrics to model how one variable (GDP) depends on another (FDI). For easier explanation of the model, we breakdown the equation.

1. Intercept 8.4473371:

The intercept is the constant term in the equation, represented by 8.4473371. This value is the predicted GDP when FDI is zero. Economically, it can be interpreted as the baseline level of GDP that would exist without any FDI. This could be due to other economic activities, domestic investments, or inherent factors within the economy that contribute to GDP independently of foreign investments.

2. Slope 0.765659:

The slope coefficient 0.765659 represents the change in GDP for every one-unit increase in FDI. This show that the influence of FDI towards GDP is weak. Specifically, it means that for each unit increase in FDI, GDP is expected to increase by approximately 0.765659 units, holding all other factors constant. This weak positive coefficient suggests a direct, positive relationship between FDI and GDP. Higher FDI levels are associated with higher GDP levels. This aligns with the general economic theory that foreign investments contribute to economic growth by bringing in capital, technology, expertise, and creating jobs, which, in turn, boost the overall economic output. The magnitude of Impact given by a specific value of 0.765659 quantifies the sensitivity of GDP to changes in FDI. While the exact interpretation depends on the units of measurement for GDP and FDI, the key takeaway is that a positive influx of FDI is associated with a proportional increase in GDP.

FDI Model: Impact of GDP on FDI

A linear Least square formulation can be illustrated as follows. Suppose we have a set of four GDP and FDI data. A set of relation for GDI and FDI data can be written as Eq. (5).

$$\left.\begin{array}{c} B_0 + B_1 GDP_1 = FDI_1 \\ B_0 + B_1 GDP_2 = FDI_2 \\ B_0 + B_1 GDP_3 = FDI_3 \\ B_0 + B_1 GDP_4 = FDI_4 \end{array}\right\} \text{Eq. (5).}$$

We can rewrite Eq. (5) in metrics form as in Eq. (6).

$$\left.\begin{bmatrix} 1 & GDP_1 \\ 1 & GDP_2 \\ 1 & GDP_3 \\ 1 & GDP_4 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \end{bmatrix} = \begin{bmatrix} FDI_1 \\ FDI_2 \\ FDI_3 \\ FDI_4 \end{bmatrix}\right\} \text{Eq. (6)}$$

Eq. (2) can be rewritten in simpler form as Eq. (7).

$$AB = y \quad \text{Eq. (7)}$$

Where

$$A = \begin{bmatrix} 1 & GDP_1 \\ 1 & GDP_2 \\ 1 & GDP_3 \\ 1 & GDP_4 \end{bmatrix}, B = \begin{bmatrix} B_0 \\ B_1 \end{bmatrix}, y = \begin{bmatrix} FDI_1 \\ FDI_2 \\ FDI_3 \\ FDI_4 \end{bmatrix}$$

To find the value of vector B, we have to derived as follows.

$$AB = y$$

$$A^T AB = A^T y$$

$$(A^T A)^{-1} A^T AB = (A^T A)^{-1} A^T y$$

$$B = (A^T A)^{-1} A^T y \quad \text{Eq. (8)}$$

We program Eq. (8) using Scilab programming. The results of the linear regression analysis for FDI model are presented in Table 4 and Table 5.

Table 4: Linear Regression Results for FDI Model (FDI as the Dependent Variable)

Variable	B_1	Standard Error	t-Statistic	p-Value
GDP	0.158339	0.13482	1.174744	0.267312
Constant	1.4344006	1.50085	0.95546	0.361872

Table 5: ANOVA Table

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.787365	1.787365	1.380024	0.267312
Residual	10	12.9517	1.29517		
Total	11	14.73906			

The regression coefficient for GDP (B_1) is weakly positive, indicating that higher GDP levels slowly attract more FDI. This claim aligns with the alternative hypothesis that investors are more likely to invest in countries with strong economic performance and growth potential. The linear regression model gathered, namely FDI model for the dataset is:

$$FDI = 1.4344006 + 0.158339GDP + \varepsilon_t$$

We then execute hypothesis test to examine the significance of B_1 value in FDI model. We state the hypothesis statement as below:

Null Hypothesis, H_0: GDP does not have a significant impact on FDI ($B_1 = 0$).

Alternative Hypothesis, H_1: GDP has a significant impact on FDI ($B_1 \neq 0$).

Since p-value $(0.267312) < \alpha(0.05)$, we do reject H_o. Therefore, we conclude that GDP has no significant impact on FDI or we do not have enough evidence to conclude that GDP influence FDI. The comparison between observed data and predicted values gathered by FDI model is given in Figure 2.

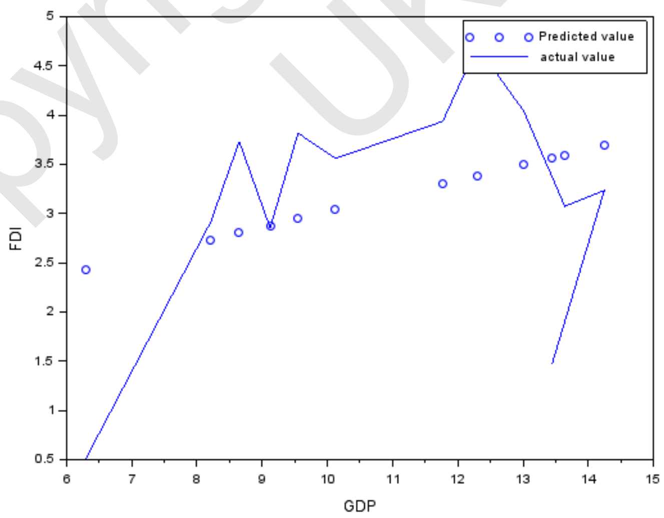

Figure 2: The Observed data vs Predicted values using FDI model.

The equation $FDI = 1.4344006 + 0.158339GDP$ is a simple linear regression model that describes the relationship between Foreign Direct Investment (FDI) and Gross Domestic Product (GDP). This equation suggests that FDI is influenced by the level of GDP, with a linear relationship between the two variables. To interpret the model, we breakdown the equation.

1. Intercept 1.4344006:

The intercept 1.4344006 represents the baseline level of FDI when GDP is zero. This is the predicted value of FDI when GDP has no contribution. Even if GDP were hypothetically zero, FDI would still have a positive value of approximately 1.4344006 units, suggesting that other factors might contribute to FDI beyond just GDP.

2. Slope 0.158339GDP:

The slope 0.158339 indicates the change in FDI for each one-unit increase in GDP. For every additional unit of GDP, FDI is expected to increase by approximately 0.158339 units. This show that the GDP weakly influence the FDI. This positive coefficient suggests that there is a direct, positive relationship between GDP and FDI. As the economy grows and GDP increases, foreign investment is likely to increase as well. This relationship aligns with economic theories suggesting that a growing economy (as measured by GDP) attracts more foreign investment. The magnitude of the slope shows how sensitive FDI is to changes in GDP. In this case, FDI increases weakly as GDP grows.

Accuracy Test

To analyses the accuracy of both models, we calculated the RMSE and MAPE for both models. Using the GDP model gathered, we predicted the GDP based on observed data. The observation and prediction are given in Table 4.

Table 4: Observed data and predicted GDP data based on GDP model.

FDI	GDP	Estimated GDP	residuals
0.512	6.299	8.839355	2.540355
2.918	8.214	10.68153	2.46753
3.733	8.649	11.30554	2.656542
2.854	9.123	10.63253	1.509528
3.818	9.551	11.37062	1.819623
3.56	10.124	11.17308	1.049083
3.938	11.769	11.4625	0.306498
4.703	12.293	12.04823	0.244769
4.042	13.008	11.54213	1.465869
3.074	13.635	10.80097	2.834027
3.2364	14.243	10.92532	3.317684
1.4639	13.439	9.568185	3.870815

The RMSE for the estimated GDP is 2.2845711 and MAPE value is 19.650706, Using the FDI model gathered, we predicted the FDI. The observation and prediction are given in Table 5.

Table 5: Observed data and predicted FDI data based on FDI model.

FDI	GDP	Estimated FDI	residuals
0.512	6.299	1.51547	4.78353
2.918	8.214	1.896434	6.317566

3.733	8.649	2.02548	6.62352
2.854	9.123	1.8863	7.2367
3.818	9.551	2.038939	7.512061
3.56	10.124	1.998087	8.125913
3.938	11.769	2.05794	9.71106
4.703	12.293	2.179069	10.11393
4.042	13.008	2.074407	10.93359
3.074	13.635	1.921135	11.71387
3.2364	14.243	1.946849	12.29615
1.4639	13.439	1.666193	11.77281

The values of MAPE indicate that GDP model is in good accuracy, while FDI model is reasonably accurate. Therefore, GDP model is more accurate than FDI model. However, RMSE shows a contradict conclusion. From RMSE values, FDI model is more accurate than GDP model. Three possible reasons for this situation are:

1. Large Variability in the Data:

Values have a wide range (e.g., some values are very large, while others are very small), MAPE can be significantly affected by errors in predicting smaller values. Even a small error in predicting a small actual value can result in a large percentage error, which would increase the MAPE. However, since RMSE is based on absolute errors, it may not be as sensitive to this, leading to a lower RMSE.

2. Scale of Errors Relative to Actual Values:

Model is consistently under- or over-estimating smaller actual values, MAPE will reflect this with a higher percentage error, even if the absolute errors (and hence RMSE) are not large. For example, predicting 1.5 when the actual value is 1.0 gives a 50% error, which can drive up MAPE, but the absolute error is only 0.5, contributing minimally to RMSE.

3. Sensitivity to Outliers in Percentage Terms:

MAPE is more sensitive to errors in small actual values because percentage errors can become disproportionately large. RMSE, being an absolute measure, is less sensitive to this, which can result in a lower RMSE compared to MAPE.

Interpretation of Results

The linear regression analysis reveals that both GDP and FDI have no significant impact on each other. FDI very weakly positive influences GDP. However, the FDI is no doubt provides essential resources that can stimulate economic growth. Conversely, there is no doubt that GDP also very weakly positive affects FDI, as higher GDP levels signal a stable and growing economy, attracting foreign investors. This finding is in contrast to Sijabat [3] but parallel to

Mohamed et al. [4] findings. Nevertheless, the B_1 value between is weak. In addition, this paper analyzes deeper and found that FDI influence GDP is stronger than GDP influence FDI. The values of MAPE indicate that GDP model is in good accuracy, while FDI model is reasonably accurate. Therefore, GDP model is more accurate than FDI model. However, RMSE shows a contradict conclusion. From RMSE values, FDI model is more accurate than GDP model. This is because RMSE is based on absolute error, while MAPE is based on relative error.

Conclusion

This study examined the relationship between GDP and FDI using a linear regression analysis approach. The results indicate a no causality between GDP and FDI. However, both variables are known for it influence to impact on each other. FDI indeed very weakly positive influences GDP by providing capital, technology, and managerial expertise, while GDP attracts FDI by signaling a stable and growing economy. We will further investigate the causality relation between these two factors by another model such as nonlinear. Since the findings of this relationship have important implications for policymakers. To foster sustainable economic growth, countries should implement policies that attract FDI, such as improving the business environment, enhancing institutional quality, and providing incentives for foreign investors. At the same time, efforts to boost GDP growth through investments in infrastructure, education, and innovation can also attract FDI, creating a virtuous cycle of economic development. It is not a waste of energy and time to investigate the exact relationship between these two factors.

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