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A Cointegration Analysis: Investigating the Long-Term Relationships among FDI Inflows, GDP, and Trade Openness in Brazil

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Abstract
Time series analysis relies heavily on the idea of stationarity to distinguish between trends that have long-lasting effects on economic variables and shocks that pass quickly. An in-depth investigation of the stationarity of important metrics, such GDP, FDI inflows, and trade openness, in the context of Brazil's economic environment reveals vital information for economic modelling and policymaking. The results found that, there is significant bi-directional causality between GDP and FDI inflows, but no substantial causal relationship between trade openness and other variables.

Keywords: FDI Inflows, Stationary, Error Correction Term, Granger Causality, Cointegration.

Introduction

International trade and capital transfers have enabled national economies to become more integrated, which has increased global economic growth as globalisation has grown. There has been much discussion in policy circles and academics over how emerging nations might quicken their economic development. One crucial explanation is that activities that promote exports and foreign direct investment (FDI) are crucial for economic development. FDI fosters the development of human capital, increases domestic investment, and transfers innovation. Nonetheless, a rise in export activity achieves economies of scale, lowers costs by exposing exporting companies to foreign competition, and stimulates more production due to comparative cost advantages across countries. Even while previous research shows that trade and foreign direct investment (FDI) have a favourable impact on economic growth, the degree to

which this benefit varies across countries depends on factors including macroeconomic stability, infrastructure, trade openness, human capital, and capital investments.

According to the well-known economists Helpman and Krugman's (1985) theory, exports increase economic growth via the use of foreign direct investment (FDI), economies of scale, and production specialisation. The growth driven hypothesis, according to Bhagwati (1988), backed the neoclassical trade theory, which contends that economic expansion increases supply and demand. Many academics have looked at the link between FDI and economic development in great detail, however the evidence is conflicting as to whether exports and FDI have a major influence on growth (Barro, 1990, 1991; Li & Liu, 2005; Lucas, 1988). The results of Romer (1986), Lucas (1988), and Balassa (1982) shown that trade openness has a favourable effect on economic development because it allows a nation that is more open to the global economy to absorb more advanced technical advancements from wealthy nations.

Research Gap

The literature now in existence delves deeply into the contributions of international commerce and foreign direct investment (FDI) to economic growth. However, the effects of these factors differ greatly across countries because of variables including macroeconomic stability, trade openness, and investment levels. It is necessary to investigate how these variables interact and affect economic outcomes.

Objectives

To investigate the long-term relationship between GDP and FDI inflows in Brazil and understand the significant impact of GDP, Trade Openness on FDI inflows using the VECM model.

Methodology

The data were collected since 2001 to 2022from the UNCTAD. This study uses various statistical tests to analyze economic variables in Brazil, including the use of Augmented Dickey Fuller and Phillips-Perron tests. The study also employs the Akaike Information Criterion to determine the best model fit. The study also employs Johansen Tests for Cointegration, long-run relationships, error correction models, Granger causality tests, and diagnostic checks, such as Lagrange-Multiplier Test for autocorrelation and Jarque-Bera Normality test. The results confirm model validity.

Johansen's cointegration methodology is employed to examine whether there exists a long-term equilibrium relationship among FDI, GDP, and Trade Openness. This methodology pivots on estimating the model defined by equation (1):

$$\Delta y_t = \propto + \varphi c_t + \sum_{i=1}^{k-1} \beta_i \Delta Y_{t-i} + \varphi y_{t-k} \varepsilon_t \qquad (1)$$

In this equation, Δ represents the first difference, y_t and y_(t-i)include the natural logarithms of FDI, GDP, and Trade Openness. Here, k is the order, C is the intercept, c_tre presents the trend term, and € is the error term. The rank of the matrix φ determines the number of cointegration vectors among the variables. In this context, Johansen (1991, 1995) proposed two cointegration tests: the trace test and the maximum eigenvalue test.

If a relationship of cointegration is detected among the variables, a Vector Error Correction (VEC) model may be used to estimate the equation that represents this cointegration. Prior to doing cointegration analysis, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests

assess the presence of stationarity. If these tests indicate that the variables exhibit a single unit root, it is necessary to apply differencing to the data before proceeding with further analysis. Cointegration occurs when variables are integrated at the same order. The VEC model is based on this cointegrating relationship.

$$\Delta y_t = \propto + \lambda ECT_t + \beta \Delta y_{t-k} \varepsilon_t \qquad (2)$$

The lagged error-correction term(s) (ECT) are derived from the long-term cointegrating relationship. The λ coefficients of the ECTs reveal how far the dependent variables vary from the long-term equilibrium. The ECTt-1 in a cointegration test quantifies the speed at which short-term values adapt to long-term values. The coefficient for the speed of adjustment should have a negative value and be less than one. Short-term estimate is conducted by calculating the first difference of the variables and employing the ECTt-1.

Finally, Granger causality tests are used to figure out the direction of cause-and-effect interactions between distinct variables in both the long and short term (Granger, 1988). This entails assessing whether the lagged independent variable coefficient β is relevant, which may be done using a basic χ2 Wald test. The error correction model (using ECT) gives another technique to test for causation. If λ is substantial, it suggests the long-term equilibrium is directly impacting the dependent variable.

Empirical Results

Stationarity Checks: Unit Root Analysis of Selected Economic Variables of Brazil

Stationarity in time series analysis denotes a situation in which series shocks are transitory in character. On the other hand, in the case of nonstationary time series, the variance and mean depend on time, and the variance shows an increasing tendency towards infinity with time (Asteriou and Hall, 2006)[1]. The behaviour of the series under investigation was closely examined using the Augmented Dickey Fuller test (Dickey and Fuller, 1981) and the Phillips-Perron test (Phillips and Perron, 1988) to determine stationarity.

From below the table, the findings of the unit root test, both at the level and the first difference, for Brazil's GDP, FDI inflows, and trade openness are shown in Table 1. These tests are essential for determining the variables' stationarity, which is a key component of time series analysis.

The results of the Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests for LNFDIINFLOWS show that the variable is stationary after differencing. For the first difference, the PP test statistic is -5.6712 with a p-value of 0.0002, and the ADF test statistic is -5.2209 with a matching p-value of 0.0005. This substantial evidence favours rejecting the null hypothesis (Ho) of non-stationarity and accepting the alternative hypothesis (H1) of stationarity.

Table 1 Unit Root Test for GDP, FDI Inflows, Trade Openness of Brazil

Variables	Level				1st Difference			
	ADF		PP `		ADF		PP	
	Test Static	P Value	Test Static	P Value	Test Static	P Value	Test Static	P Value
Lnfdi Inflows	-1.5367	0.496	-1.3438	0.5892	-5.2209	0.0005	-5.6712	0.0002
Lngdp Lntrade	-1.9575	0.3017	-1.9575	0.3017	-3.1085	0.0421	-3.1085	0.0421
Openness	-0.2303	0.9201	-0.2303	0.9201	-4.09	0.0021	-4.5347	0.0021

1 Asteriou and Hall (2006), Applied Econometrics, Pp.288.

Ho: There is non-stationary

H1: There is stationary

The ADF and PP tests also point to stationarity for LNGDP after differencing. The results of both tests show that LNGDP becomes stationary in first differences, with identical statistics of -3.1085 and p-values of 0.0421.

On the other hand, LNTRADEOPENNESS has a somewhat different trend. The tests conducted after differencing provide strong evidence of stationarity, even if the ADF and PP tests at the level are unable to reject the null hypothesis of non-stationarity. For the first difference, the ADF and PP test statistics are -4.090 and -4.5347, respectively, with matching p-values of 0.0021.

The significance of these findings for our research lies in their validation of the variables' fit for time series modelling, which guarantees the accuracy of the studies that follow. They provide credence to the idea that LNFDIINFLOWS, LNGDP, and LNTRADEOPENNESS show stationary behaviour after differencing, which makes it easier to study how their dynamics and interactions change over time in the Brazilian setting.

Rank Selection Criterion

One of the most important challenges facing statisticians the analysis of datasets is identifying which variables are most important to include in their models. The best fitting model and a model's dimensionality are two topics of discussion surrounding data mining that have gained popularity in the statistical literature. Regression frameworks have used two different methods to calculate lag length: theoretical information criteria (IC) and likelihood ratio tests for comparing nested models.

Enders (2004) and Davidson and MacKinnon (2004) support the likelihood ratio test technique, which is often used in combination with a stepwise procedure to find relevant variables in a model. Many contend, however, that the stepwise strategy's sequence of variable selection lacks theoretical justification. According to Burnham and Anderson, likelihood ratio tests that rely on arbitrary significant thresholds may not be feasible for models that are not nested inside larger models and provide difficulties for a variety of tests. Given these drawbacks, the IC method created by Akaike (1973) is seen to be a better option.

The IC method is independent of whether a model is nested within another or on a predetermined relevance threshold. Its goal is to fit a dataset to many competing models and determine which model best matches the data. Since Akaike initially derived the well-known information criterion (AIC) using the connection between the anticipated log-likelihood of a model and the sufficiency theorem of Klinkback-Leibler, information theoretic criteria have changed (Grary David Sharp 2010)[2].

Table 2 Lag Selection Criterion

Maximum Lag	LL	SBIC	HQIC	AIC
0	9.5756	-.582227	-.710161	-.730623
1	35.3804	-2.00424	-2.51597	-2.59782
2	39.8404	-1.05461	-1.95014	-2.09337
3	46.8919	-.392927	-1.67226	-1.87688
4	87.4062	-3.44933*	-5.11246*	-5.37846*

Above the table provides the selection of the rank based on Akaike Information Criterion, Hannan-Quinn Information Criterion, and Schwarz Bayesian Information Criterion, helps determine

2 David D S (2010)," Lag Length Selection for Vector Error Correction Models" Rhodes University, Pp.46.

the best lag order for a research study. The log-likelihood (LL) at lag 0 is 9.5756, but increases to 35.3804 as lag 1 approaches. At lags two and three, LL increases significantly to 87.4062, indicating a notable improvement in model fit. Therefore, lag 4 is the best option, offering the best explanatory power and model fit for the analysis of lnfdi inflows, lngdp, and lntradeopenness.

Johansen Tests for Cointegration

To determine equilibrium or a long-term connection between the variables, the cointegration test was used. The variables were cointegrated and divergence towards the long-run equilibrium route was limited if there existed a long-term link between them. The majority of the issues with the Engle and Granger approach were addressed by the Johansen and Juselius (1990) procedure. These issues included (i) the order of integration in the EG approach, (ii) the possibility of multiple cointegrating relationships when dealing with more than two variables, and (iii) the two-step approach it relies on. Based on maximum likelihood estimations, the Johansen and Juselius (1990) method provides maximum Eigen Value and Trace statistic for identifying the number of cointegrating vectors.

The Unrestricted Cointegration Rank Test (Trace) findings, which were obtained by using Johanson Maximum Likelihood Estimation to investigate the link between Brazil's GDP, trade openness, and FDI inflows, are shown in Table 3. The test looks at numbers of cointegrating equations (CEs) that have been hypothesised in order to find out whether there are any long-term connections between the variables

Table 3 Unrestricted Cointegration Rank Test (Trace) of FDI Inflows, GDP, and Trade Openness of Brazil (Johanson Maximum Likelihood Estimation)

Hypothesized No of CE(s)	Eigenvalue	Trace Statistics	0.05 Percent Level of Significance	P-Value
None*	0.7246	35.9233	29.7970	0.0087
At most 1	0.4029	11.4169	15.4947	0.1871

The hypothesis of "None" implies that no cointegrating equations exist between the variables. However, the calculated eigenvalue of 0.7246, as well as the resulting trace statistic of 35.9233, substantially exceeds the critical value at the 0.05 percent level of significance (29.7970), yielding a p-value of 0.0087. This provides strong evidence against the null hypothesis, implying the existence of at least one cointegrating equation between the variables.

According to the hypothesis "At most 1," there can only be one cointegrating equation. Here, the decreased trace statistic is 11.4169 due to the eigenvalue decreasing to 0.4029. At the 0.05 percent significance threshold, the statistic still above the critical value (15.4947). Therefore, even though it is getting close to significance, the p-value of 0.1871 shows that there is not enough data to rule out the hypothesis that there is only one cointegrating equation.

Table 4 Unrestricted Cointegration Rank Test (Maximum Eigenvalue) of FDI Inflows, GDP, and Trade Openness of Brazil

Hypothesized No of CE(s)	Eigenvalue	Maximum Eigenvalue Statistics	0.05 Percent Level of Significance	P-Value
None*	0.7246	24.5064	21.13162	0.0161
At most 1*	0.4029	9.8000	14.26460	0.2254

The calculated eigenvalue corresponding to the null hypothesis of cointegration (None*) is 0.7246. The calculated value of the maximal eigenvalue statistic, which quantifies the strength

of the cointegrating relationship, is 24.5064. The obtained p-value of 0.0161 indicates that the null hypothesis is rejected, as it surpasses the critical value of 21.13162 at the 0.05 percent level of significance. Therefore, it can be deduced that the variables exhibit at least one cointegrating relationship, as supported by substantial evidence.

In contrast, the eigenvalue decreases to 0.4029 when the hypothesis of a single cointegrating relationship (At most 1*) is considered. As a result, the maximal eigenvalue statistic falls to 9.8000, which is less than the critical value of 14.26460 at the 0.05 percent level of significance. A p-value of 0.2254 indicates that it is unable to reject the null hypothesis. This implies that the variables might exhibit a cointegrating relationship of no more than one, despite the lack of statistical significance at conventional thresholds.

The p-values for both tests are notably zero, further emphasizing the statistical importance of the results. These findings indicate that there is a long-term link between the variables under investigation and that they are actually cointegrated.

Table 5 Long-Run Relationships Among the Variables FDI Inflows, GDP, and Trade Openness of Brazil

Variable	Coefficient	Std.Err	Z	P-Value
LNGDP	-1.3098	0.0882	-14.84	0.000
LNTRADEOPENNESS	0.3245	0.4087	0.79	0.427
CONS	7.020	-	-	-

Note: Dependent Variable LNFDIINFLOWS

The results from the long-run relationship between the variables from above the table revealed that, the coefficient of GDP -1.309821 indicates that a one-unit rise in the variable GDP leads in a 1.309821-unit increase in the dependent variable over time, while other variables remain constant. Similarly, the coefficient Trade Openness 0.3245633 indicates a one-unit increase in Trade Openness leads to a decrease in the dependent variable, but its p-value is high, making its relationship unreliable, which means that Trade Openness does not have any impact on FDI inflows in Brazil.

Table 6 Error Correction Model Results for FDI Inflows, GDP, and Trade Openness of Brazil

Variable	Coefficient	Std.Err	Z	P-Value
_CONS	-.00068	-	-	-
INFDI INFLOWS	.0113	.3267	0.03	0.972
LNGDP	.1805	.8522	0.21	0.832
LNTRADE OPENNESS	.7310	1.0860	0.67	0.501
_EC1	-1.2829	.4682	-2.74	0.006

The Error Correction Term (_EC1) has a substantial negative coefficient (-1.2829) with a standard error of 0.4682. This implies that deviations from the long-run equilibrium of the variables are corrected at a rate of around 1.2829 units each period. The substantial p-value of 0.006 suggests that this term has a statistically significant effect on the adjustment process towards equilibrium.

Granger Causality

Table 7 shows the findings of the Granger Causality Test for FDI Inflows, GDP, and Trade Openness with 21 observations in Brazil. This statistical research seeks to identify associations between these major economic factors. The null hypotheses investigated are whether one variable affects another.

Table 7 Granger Causality Test for FDI Inflows, GDP, Trade Openness of Brazil

Equation	Null Hypothesis	F Statistics	P-Value
FDI Inflows	GDP Does not cause FDI Inflows	16.407	0.000
	Trade Openness Does not cause FDI Inflows	.04077	0.840
GDP	FDI Inflows Does not cause GDP	7.7478	0.005
	Trade Openness Does not cause GDP	.05626	0.813
Trade Openness	FDI Inflows Does not cause Trade Openness	.02565	0.873
	GDP Does not cause Trade Openness	.00184	0.966

From the table 7, the F-statistic of 16.407, suggests that there is a substantial association between Brazil's GDP and FDI inflows. There is significant proof to reject the null hypothesis of GDP Does not cause FDI Inflows, since the p-value of 0.000 is less than the typical significance threshold of 0.05. Thus, we draw the conclusion that FDI inflows to Brazil are Granger-caused by GDP. Similarly, the analysis discovered that for second hypothesis, with a P-Value of 0.813, which suggests that changes in Trade Openness are not significant, there is not enough data to support the null hypothesis that Trade Openness does not substantially affect GDP.

The thirdly, the null hypothesis states that FDI inflows do not impact GDP. However, the F statistics show that FDI inflows do cause GDP, with a P-value of 0.005 and a significant degree of rejection ($p < 0.01$). This suggests a relationship between changes in GDP and changes in FDI inflows.

The findings also reveal for the fourth hypothesis that trade openness does not significantly impact GDP, as evidenced by the F-statistic of 0.05626 and a p-value of 0.813.

It also suggests that foreign direct investment inflows do not impact trade openness, with the F-statistic of 0.02565 and a p-value of 0.873. Furthermore, the F-statistic of 0.00184 and a p-value of 0.966 do not justify rejecting the null hypothesis, suggesting that trade openness and GDP are not significantly correlated. Therefore, trade openness is not a significant factor in determining GDP.

These findings provide important new information on the causal relationships between GDP, FDI inflows, and trade openness. In particular, GDP seems to be a major driver of FDI inflows and GDP itself, and there is bi-directional causality between GDP, and FDI Inflows, while trade openness does not seem to have a substantial causal relationship with any of these variables which means that there is independent causality between them.

Diagnostic Checking

The diagnostic checking findings from study are critical for determining the model's validity and dependability. Beginning with the Lagrange-Multiplier Test (LM), which tests for autocorrelation are as,

Table 8 Diagnostic Checking

Lagrange-Multiplier Test (LM)			
Hypothesis	**Lag**	**F-Statistics**	**P-value**
H0: No Autocorrelation	1	6.0462	0.73529
	2	3.8983	0.91798
	3	10.0472	0.34668
	4	16.4282	0.06846
Jarque-Bera Normality test			
H0:Data Normally Distributed	Equation	F-Statistics	P-value
	D_lnfdiinflows	0.584	0.74672
	D_lngdp	0.160	0.92291
	D_lntradeopenness	1.099	0.57722
Eigenvalue Stability Condition			
Stable			

The F-statistic of 6.0462 at lag 1 and the p-value of 0.73529 show that there is no substantial autocorrelation at this latency, implying that are unable to reject the null hypothesis. Similarly, for lags 2 and 3, with F-statistics of 3.8983 and 10.0472, respectively, and corresponding p-values of 0.91798 and 0.34668, do not reject the null hypothesis. At lag 4, specifically, the corresponding p-value of 0.06846 indicates a propensity to reject the null hypothesis, but not to the extent that would be considered significant at conventional levels.

This is where find the greatest F-statistic of 16.4282.

Moving on to the Jarque-Bera Normality test, which assesses the assumption of normality in data, get comforting findings. D_lnfdiinflows, D_lngdp, and D_lntradeopenness all have

F-statistics that are not substantially different from what would be anticipated under normalcy, as indicated by p-values of 0.74672, 0.92291, and 0.57722. As a result, it fails to reject the null hypothesis, suggesting that data has a normal distribution.

Finally, the Eigenvalue Stability Condition offers critical information about the stability of model. The "Stable" categorization indicates that the eigenvalues linked with model's coefficients match the stability criteria, which reinforces the robustness of results.

In summary, while the Lagrange-Multiplier Test indicates that, there is no potential issue with autocorrelation at lag up to 4, the overall diagnostics support the validity of our model, with significant violations of autocorrelation or normality assumptions, and stability confirmed by the Eigenvalue Stability Condition.

Suggestion

The study reveals that trade openness does not significantly impact foreign direct investment, GDP. The inconclusive impact of trade openness on GDP and FDI necessitates further investigation, suggesting that strengthening trade policies and agreements could potentially enhance its benefits.

Conclusion

The analysis of economic variables in Brazil, including GDP, FDI inflows, and trade openness, was conducted using VECM model. Results showed that LNFDIINFLOWS and LNGDP

exhibit stationary behavior, while LNTRADEOPENNESS also shows stationarity. The Akaike Information Criterion (AIC) was used to determine the lag order for the models, with Lag 4 being the best option. Cointegration tests were conducted to identify long-term relationships between variables, with at least one cointegrating equation found. Long-run relationships showed that GDP significantly impacts FDI inflows, while trade openness's impact is inconclusive. The Error Correction Model results indicated a significant negative effect on the adjustment process towards equilibrium. There is significant bi-directional causality between GDP and FDI inflows, but no substantial causal relationship between trade openness and other variables. Diagnostic tests like the Lagrange-Multiplier Test and Jarque-Bera Normality test confirmed the model's stability.

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