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Analysis of the Relationship Between Net Exports and Gross Regional Domestic Product Using the Panel Vector Correction Model (PVECM) Approach

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ABSTRACT

In regional economic growth, various factors play a role, including net exports, a key indicator of international trade. The purpose of this study is to analyze the long-term relationship and causal link between net exports and Gross Regional Domestic Product (GRDP) in Indonesia. The method used in this study is the Panel Vector Error Correction Model (PVECM), applied to panel data from 34 provinces in Indonesia for the period 2010–2023. The results of the study indicate a cointegration relationship between net exports and GRDP, in which a 1-unit increase in net exports decreases GRDP by 5.445139 units. The Granger Causality test shows a significant bidirectional relationship between the variables, indicating that they influence each other. The R^2 value of 54.99% indicates that the model explains 54.99% of the variation in net exports. The implication of these findings suggests that policymakers need to consider the quality and composition of export and import activities, as well as regional trade structures, to ensure that international trade contributes positively to regional economic growth.

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A. INTRODUCTION

Economic development aims to improve people's welfare, with economic growth as the main indicator in assessing its success. One measure of a region's economic growth is the Gross Regional Domestic Product (GRDP), which reflects the structure and pace of economic development (Ali et al., 2023). In Keynesian theory, GRDP is influenced by household consumption, investment, government spending, and net export (Yahya et al., 2022).

Net exports, as the difference between exports and imports, play an important role in driving economic growth through increased aggregate demand. When net exports are positive (trade surplus), this indicates that a country becomes a net exporter of goods and services, which can increase GDP and support domestic economic growth. The relationship between exports, imports, and net exports is very important in understanding the economic dynamics of a country (Tampubolon & Loh, 2020). Thus, the relationship between net exports and GRDP needs further analysis, as international trade can affect a region's economic stability (Mpojota, 2025).

One of the challenges in economic research is the reciprocal relationship between economic indicators and the limitations of the data used in analysis. To overcome these obstacles, panel data is used, which combines time-series and cross-sectional data, thereby enabling more accurate analysis of two-way relationships (Zyphur et al., 2020). Causality analysis in panel data can be done using the Panel Vector Error Correction Model (PVECM) (Apostu et al., 2022). The PVECM approach can identify cointegration and short- and long-term relationships among economic variables by capturing imbalances among variables through an error-correction mechanism (Nkalu et al., 2020).

Based on this description, this study aims to analyze the relationship between net exports and GRDP using the PVECM method. Panel Vector Error Correction Model (PVECM) is an approach that seeks to analyze the causal relationship between variables, where each variable is considered to influence the other (cause each other) (Suryanto et al., 2023). This method was chosen for its ability to capture potential bidirectional relationships and cointegration between the two variables (Ikpesu, 2020). Previous research aimed to identify economic factors influencing population food security in the short and long-term using the PVECM. The results showed that the population food security model in food-insecure provinces on Java Island shifted from short-term to long-term equilibrium, with a relatively rapid adjustment rate (Aneja et al. 2017). The novelty of this study lies in the use of the PVECM, which has never been applied to Indonesian Net Exports and GRDP data. To date, research examining the relationship between net exports and GRDP has focused primarily on regression and correlation models. Therefore, this study is novel and is expected to provide new insights and perspectives on the relationship between variables from a panel-data perspective, particularly those that are cointegrated. Hopefully, the results of this study can reveal significant cointegration and causality relationships, which, in turn, can serve as a basis for designing more effective strategies and policies to promote economic growth in Indonesia. Unlike those studies, this research investigates the relationship between net exports and Gross /Regional Domestic Product (GRDP) across 34 provinces in Indonesia, explicitly using the latest data from 2010 to 2023.

B. RESEARCH METHOD

The data used in this study are time-series data collected by the Central Bureau of Statistics (BPS) on GRDP and Net exports per year for each province in Indonesia. With the research sample used, GRDP and Net Exports of 34 Provinces in Indonesia in the form of annual data during 2010-2023. The variables used in the study are as follows.

Data analysis in this study uses the Panel Vector Error Correction Model (PVECM) approach, which is carried out with the help of Eviews 12 software. The stages of data analysis that can be carried out are as follows:

1. Retrieval of data on GRDP and Net Exports of Indonesia in 2010-2023 on the BPS website.
2. Perform descriptive statistical analysis.
3. Perform a stationarity test on panel data.

   In PVECM analysis, stationarity testing often uses the IPS method (Srithilat et al., 2018). IPS is a developed form of the LLC test that assumes errors are autocorrelated and that the T value remains constant. To calculate the IPS test (tips), the first step that needs to be done is the calculation for the ADF statistics of the time series in each individual unit (tpi) with $i = 1, 2, \ldots, N$ then N is the number of cross-section units described in the following model:

$$Y_{i,t} = \mu + \phi_i Y_{i,t-1} + \varepsilon_{i,t}, i = 1, 2, \ldots, N;\ t = 1, 2, \ldots, T \quad (1)$$

   Which:

i	:	i-th cross-section unit, representing individuals or entities in the panel data
N	:	number of cross-section units in the data
t	:	t-th time unit, representing the time period in the panel data
T	:	number of time units or length of data
$Y_{i,t}$	:	endogenous variable of the i-th cross section unit at time t
$Y_{i,t-1}$	:	lag of endogenous variable Y at the i-th cross section unit at the t-th time $(t-1)$
μ	:	constant parameter value
ϕi	:	the expected value of the AR(1) parameter for the i-th cross-section unit
$\varepsilon_{i,t}$	:	error value

4. Determine the optimum lag length.

   Determining the optimal lag is important in VECM modeling (Suharsono et al., 2017). The selection of the lag length for the model's variables should be carefully considered to minimize potential errors. If the lag is too long, the number of parameters to be estimated will increase. Consequently, this may reduce the degrees of freedom due to the number of additional parameters used. The criterion that can be used in determining the optimum lag length in this study is Akaike's information criterion (AIC) (Pratiwi et al., 2022).

$$AIC = \ln\left(\frac{RSS}{N}\right) + \frac{2k}{N} \tag{2}$$

Which:

RSS : sum of squared residuals
k : number of parameter variables estimated in the model
N : number of observations
$\hat{Y}_i$: Estimator of Y (Value estimated by the regression line)

5. Conduct a Vector Auto Regression (VAR) stability test.
The VAR model is considered stable if all roots are inside the unit circle, so the resulting IRF and FEVD results can be declared valid (Zahariev et al., 2022). In the VAR stability test the hypothesis used is as follows:

H_0 : $|z| > 1$ (VAR is unstable)
H_1 : $|z| < 1$ (VAR stable)

Testing criteria:
Reject H_0, if the values of all roots of the characteristic polynomial < 1.
Fail to reject H_0, if the value of all roots of the characteristic polynomial > 1.

6. Perform a panel data cointegration test.
The cointegration test is used to identify the existence of a long-term relationship between variables that meet the integration requirements, namely that all variables are stationary at the first-difference level. This cointegration test is also important to prevent false regression or poor analysis results (Lau et al., 2019). The Johansen Cointegration method is one of the methods used to identify cointegration between variables. This method helps determine whether a long-term relationship exists between variables in a model. In accordance with Ma'rifah (2019), the hypothesis used in this test is as follows:

H_0 : $r = 0$ (there is no cointegration)
H_1 : $r < 0$ (there is cointegration)

The test statistics to use in this case are trace statistics. Trace statistics are calculated by summing up the r-th largest eigenvalue +1 to k, which is expressed by the following formula:

$$\begin{aligned} LR_{tr}\,(r|k) &= -T\sum_{i=r+1}^{k}\log\left(1-\lambda_i\right) \\ \text{which, } \Pi &= \sum_{i=1}^{p} A_i - 1 \end{aligned} \tag{3}$$

which:

LR : cointegration
λ_i : the I-th largest eigenvalue of the matrix Π
k : many endogenous variables
r : rank of cointegration vector
A_i : coefficient matrix
p : lag VAR

7. Estimating the PVECM Model.
The Vector Error Correction Model is a widely used approach in economic research for modeling multivariate time series. When this model is applied to panel data, it yields the Panel Vector Error Correction Model (PVECM), which can be used in various analyses combining cross-section and time-series data. The general model of the PVECM system of linear equations is as follows (Apostu et al., 2022).

$$\Delta Y_{i,t} = \alpha + \lambda ECT_{i,t-1} + \sum_{k=1}^{p} \beta_k \Delta Y_{i,t-k} + \sum_{k=1}^{p} \delta_k \Delta X_{i,t-k} + \varepsilon_{i,t} \tag{4}$$

which:

$\Delta Y_{i,t}$	:	change or first differencing of variable Y
$ECT_{\mathrm{i,t-1}}$	:	error correction term
α	:	intercept
λ	:	Adjustment coefficient
β_k	:	coefficient of lag change in variable Y
δ_k	:	coefficient of lag change in variable X
$\varepsilon_{i,t}$	:	error Value

8. Testing Granger Kausality on Panel Data.
   The Granger Causality Test is used to identify the cause-and-effect relationship between two variables, i.e., whether one variable has a significant influence on the other in one direction or two directions. This test aims to determine whether an endogenous variable can be considered an exogenous variable, as well as evaluate the effect of the historical value of a variable on the condition of another variable at present, without considering the unit of measurement (Kębłowski, 2016).
9. Furthermore, detecting (IRF).
   IRF is used to evaluate the presence of shocks from endogenous variables to other variables, as well as to estimate the duration of their impact. With IRF, we can analyze how a one-standard-deviation change in an independent variable affects other variables. It also allows us to track the impact of the shock, which is usually one standard error. IRF helps determine how long the effect of a shock will last and how long it will take for the variables to return to equilibrium after the shock.
10. Perform Variance Decomposition (VD) analysis.
   Variance decomposition (VD), or Forecast Error Variance Decomposition (FEVD), is a method in the VAR/VECM model that provides information on how much influence a shock to one variable has on other variables, both in the current period and in the future. FEVD shows the importance of each variable in the VAR/VECM model by assessing the extent to which each variable can explain other variables or itself in response to a shock. Through variance decomposition analysis, we can understand the changes that occur before and after the shock, both caused by the variable itself and other variables.

C. RESULT AND DISCUSSION

1. Descriptive Analysis

This study uses panel data with cross-sectional units of 34 provinces in Indonesia and time-series units consisting of annual data from 2010 to 2023. The following are descriptive statistics and data plots of each variable used. The descriptive statistics variable is presented in Table 1.

Table 1. Descriptive Statistics

Variables	Minimum	Maximum	Average	Standard Deviation
GRDP	14,983,911.88	2,050,465,970.18	283,932,483.68	407,205,342.5
Net Export	-285,203,341.2	276,810,646.91	13,000,055.98	70,006,186.75

Based on Table 1, the total GRDP in Indonesia from 2010 to 2023 has a standard deviation of 407,205,342.5. The lowest GRDP is 14,983,911.88 million, and the highest is 2,050,465,970.18 million, with an average GRDP of 283,932,483.68 million across 34 provinces in Indonesia. As for Net Exports in Indonesia from 2010 to 2023, the standard deviation is 70,006,186.75. With an average Net Export of 13,000,055.98 million in 34 provinces in Indonesia.

The descriptive analysis shows a considerable disparity in Gross Regional Domestic Product (GRDP) across provinces in Indonesia. The wide gap between the lowest and highest values, along with the relatively large standard deviation, indicates that economic activity is not evenly distributed, with certain provinces contributing far more significantly than others. In contrast, Net Exports appear relatively small relative to average GDP, suggesting that international trade has not yet become the primary driver of regional economies. These findings highlight the need for policies that encourage more balanced economic development across provinces and promote the optimization of regional export potential.

2. Stationarity Test

In PVECM modeling, the test used to see stationarity is the IPS test, which is the LM test. The following stationarity test results are presented in Table 2.

H_0 : $\phi i \geq 1$ for all i (non-stationary)
H_1 : $\phi i < 1$ for all i (stationary)

Table 2. IPS Stationarity Test at the Level

Variables	Statistic	Probability (P-Value)
GRDP	6.26943	1.0000
Net Export	3.52599	0.9998

Based on Table 2, the stationarity test at the level, the analysis results show that the GRDP and Net Export variables are not stationary because the value of each test statistic is greater than the critical table value and the p-value is greater than the significance level α = 0.05. Thus, both variables still contain unit roots. Therefore, further differentiation is required to render the data stationary before they are used in the PVECM analysis. The results of the stationarity test at the first difference level are presented in Table 3.

Table 3. IPS First Difference Stationarity Test

Variables	Statistic	Probability (P-Value)
GRDP	-5.13808	0.0000
Net Export	-6.01230	0.0000

Based on Table 3, the results of the stationarity test at the first-difference level indicate that the GRDP and Net Export variables are stationary, as evidenced by the test statistic being smaller than the critical value and the p-value being smaller than α = 0.05. This indicates that both variables no longer exhibit unit roots, so further analysis using the PVECM method can proceed.

3. Determining the Optimum Lag Length

Determination of the optimal lag length selected is by selecting from all existing criteria that have the smallest value and have an asterisk (*) from all lags proposed, then the lag is the optimal lag. The results of the optimal lag-length determination are presented in Table 4.

Table 4. Determination of the Optimal Lag Length

Lag	AIC	SC	HQ
0	71.27661	71.29759	71.28494
1	70.59668	70.56964	70.62168
2	70.38490*	70.48983*	70.42656*

Based on Table 4, seen from all criteria, the one with the smallest value and the most asterisks is at lag 2. It can be concluded that the maximum influence of a variable on other variables occurs at a lag of two periods. Therefore, for the next estimation, the model used will include a two-period lag as a reference.

4. Vector Auto Regression (VAR) Stability Test

VAR stability is said to be stable if the modulus value of all roots of the characteristic polynomial < 1, so that the resulting IRF and FEVD are considered valid. The following VAR stability test results are presented in Table 5.

H_0 : $|z| > 1$ (VAR is unstable)
H_1 : $|z| < 1$ (VAR stable)

Table 5. Var Stability Test

Root	Modulus
0.875744	0.875744
0.018018 - 0.505347i	0.505669
0.018018 - 0.505347i	0.505669
-0.280954	0.280954

Based on Table 5, the result shows that the modulus value of all roots of the characteristic polynomial < is 1, which means H_0 is rejected. It can be concluded that the VAR is stable, and the resulting IRF and FEVD are therefore valid. The graphical form of the VAR stability test is as follows.

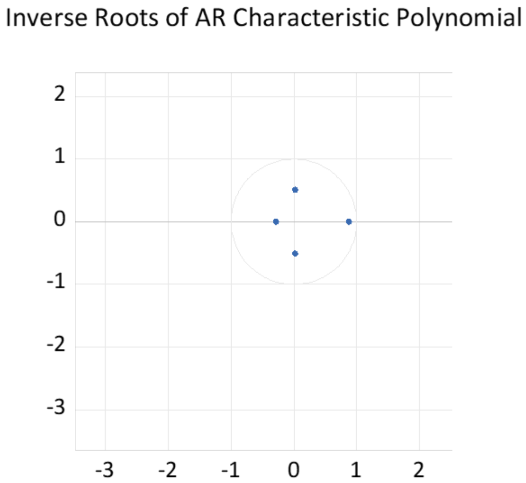

Figure 1. Vector Auto Regression (VAR) Stability Test Chart

Based on Figure 1, it can be seen that all roots of the characteristic polynomial are inside the unit circle (radius 1). The position of all points inside the circle indicates that the estimated VECM model meets the stability criteria. Thus, the model is valid and can be used to study the dynamic relationships among the variables in the study.

5. Cointegration Test

In the panel data cointegration test, the test used is Johansen Cointegration which is one approach that can be used in identifying the cointegration relationship between variables. The test statistics used are trace statistics, the following cointegration test results are presented in Table 6.

Table 6. Cointegration Testing

Hypothesized No. of CE	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None*	0.392915	174.9767	15.49471	0.0000
At most 1*	0.015431	5.287302	3.841465	0.0215

Based on Table 6, the trace statistic value at None* (174.9767) is greater than the critical value at the 5% confidence level (0.05) (15.49471). So it can be interpreted that there is a cointegration or long-term relationship between the variables used in this study.

6. PVECM Model Estimation

Since the data are stationary at the first-difference level and exhibit cointegration, the PVECM method can be used to analyze the long-term relationship between GRDP and Net Export. PVECM estimates are considered significant if the t-statistic exceeds the t-table value at the 5% significance level. The t-table value with a significance level of 5% in this study is 1.965. If the t-statistic is greater than 1.965, the PVECM estimation results are considered significant. The following PVECM model estimation results are presented in Tables 7 and 8.

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Table 7. Long-term Relationship

Cointegrating Eq:	CointEq1	
Δ(GRDP,-1)	1.000000	
Δ(NetEkspor,-1)	-5.445139 (0.0000) [-19.6351]	
C	1,889,278	
Error Correction:	**Δ(PDRB,2)**	**Δ(NetExport,2)**
CointEq1	-0.150169 (0.03131) [-4.79683]	0.204491 (0.01555) [13.1509]

Based on Table 7, in the long run, the relationship between net exports and GRDP is negative and significant, as indicated by the coefficient value of -5.445139. This means that every 1-unit increase in net exports will decrease GRDP by 5.445139 units. The constant value of 1,889,278 indicates that, in the long run, the equilibrium level of GRDP will be reached when other factors remain stable.

Table 8. Short-term PVECM Result

Error Correction:	D(GRDP,2)	D(NetExport,2)
D(GRDP(-1),2)	-0.381742 -0.05263 [-7.25319]	-0.129708 -0.02614 [-4.96174]
D(GRDP(-2),2)	-0.248446 -0.05076 [-4.89421]	-0.134258 -0.02521 [-5.32472]
D(NetExport(-1),2)	-0.883009 -0.12822 [-6.88644]	0.201255 -0.06369 [3.15998]
D(NetExport(-2),2)	-0,334795 -0,10426 [-3,21123]	0.032532 -0.05178 [-0.62822]
C	1,323,237 -801,096 [1.65178]	-262,053.6 -397,903 [-0.65859]
R-squared	0.330167	0.549938
Adj. R-squared	0.320140	0.543201

Based on Table 7 and Table 8, the general PVECM model is obtained as follows:

$$\begin{aligned}
\Delta \text{GRDP}_{i,t} &= \alpha_1 + \lambda_1 \text{ECT}_{i,t-1} + \sum_{k=1}^{p} \beta_{1k} \Delta \text{GRDP}_{i,t-k} \sum_{k=1}^{p} \Delta \text{Net Export}_{i,t-k} + \varepsilon_{1i,t} \\
\Delta \text{GRDP}_{i,t} &= 1,323,237 - 0.150169\ \text{ECT}_{i,t-1} - 0.3817\ \Delta \text{GRDP}_{i,t-1} - 0.2484\ \Delta \text{GRDP}_{i,t-2} \\
&\quad -0.8830\ \Delta \text{Net Export}_{i,t-1} - 0.3348\ \Delta \text{Net Export}_{i,t-2} + \varepsilon_{1i,t}
\end{aligned}$$

$$\begin{aligned}
\Delta \text{Net Export}_{i,t} &= \alpha_2 + \lambda_2 \text{ECT}_{i,t-1} + \sum_{k=1}^{p} \beta_{2k} \Delta \text{GRDP}_{i,t-k} + \sum_{k=1}^{p} \delta_{2k} \Delta \text{Net Export}_{i,t-k} + \varepsilon_{2i,t} \\
\Delta \text{Net Export}_{i,t} &= -262,053.6 + 0.204491\ \text{ECT}_{t-1} - 0.12970\ \Delta \text{GRDP}_{t-1} - 0.13425\ \Delta \text{GRDP}_{t-2} \\
&\quad +0.201255\ \Delta \text{Net Export}_{t-1} - 0.32532\ \Delta \text{Net Export}_{t-2} + \varepsilon_{2,t}
\end{aligned}$$

The findings of this research indicate that the relationship between Net Export and GRDP in the long run is negative and significant, with a coefficient of -5.445139, indicating that a one-unit increase in Net Export decreases GRDP by 5.445139 units.

The constant 1,889,278 indicates the long-term equilibrium of GRDP. In the short run, the Error Correction Term (ECT) of 0.204491 indicates that about 20.45% of the imbalance is adjusted each period, with faster adjustment in Net Export. The first lag of ΔGRDP hurts ΔNetExports, while the first lag of ΔNetExports has a positive impact on the current Net. The R^2 value of 0.549938 indicates that the model explains 54.99% of the variation in Net Export, while the model's variables explain 33.02% of the variation in GRDP.

7. Granger Causality Test

The VEC Granger Causality/Block Exogeneity Wald Test is used to identify the causal relationship between variables. The following granger causality test results are presented in Table 9.

Table 9. Granger Causality Test

Variables	First Causality	Second Causality	Causality Results
GRDP and Net Exports	0.0000	0.0000	Two-way causality GRDP ↔ Net Exports

Based on Table 9, it can be seen that GRDP and Net Exports in the previous two-year period have a significant effect, with a prob value smaller than alpha (0.0000) at lag-2, indicating a two-way causality relationship between Net Exports and Indonesian GRDP.

8. Impulse Response Function (IRF)

The Impulse Response Function (IRF) shows how an endogenous variable responds to a shock to a particular variable over time, including the duration of the effect. The results of the IRF analysis can be seen in the following section:

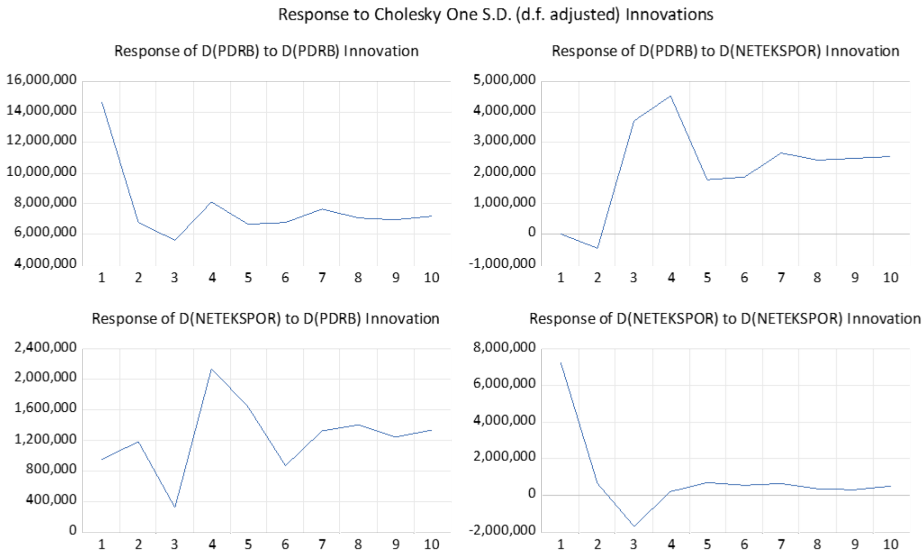

Figure 2. Response and Contribution of Net Exports to GRDP

Based on Figure 2, the response to a shock in the Net Export variable shows a dynamic pattern: an initial positive response, then turning negative in the second to third periods, increasing again in the third to fifth periods, and then fluctuating in the fifth to tenth periods. Meanwhile, the response of GRDP to the Net Export shock shows a negative pattern at first, then turns positive in the second and third periods, and fluctuates until the tenth period, though the intensity of the fluctuations decreases. The IRF results indicate that Net Exports have a significant influence on GRDP, with dynamic inter-variable relationships that are influenced by various other economic factors.

This aligns with previous research, which found that the relationship between exports, imports, and net exports is crucial for understanding a country's economic dynamics (Tampubolon & Loh, 2020). The novelty of this study's results is that there is a relationship between net exports and GRDP, considering both cross-sectional and non-stationary time-series data, where panel data will be more informative than cross-sectional data alone. The novelty of this study also provides information on the long-term and short-term relationship between net exports and GRDP, which, when compared to previous research that discussed the relationship between exports and imports to GRDP in Central Java without considering long-term or short-term relationships (Nainggolan et al., 2023).

9. Variance Decomposition (VD)

Variance Decomposition (VD) provides an estimate of the extent to which a variable contributes to changes in itself and other variables over time, measured as a percentage.

Table 10. Variance Decomposition (Net Export)

Period	S.E.	D(Net Exports)	D(GRDP)
1	7270162	100,0000	0,000000
2	7392119	97,84493	2,155068
3	7584094	97,45094	2,549059
4	7881868	90,62280	9,377199
5	8080393	87,45658	12,54342
6	8145970	86,73346	13,26654
7	8277106	84,95004	15,04996
8	8402895	82,86282	17,13718
9	8500119	81,30137	18,69863
10	8617885	79,68341	20,31659

Based on Table 10, the variance decomposition results show that in the first period, Net Export is fully influenced by itself with a 100% contribution, while GRDP does not contribute. However, starting from the second period, the contribution of GRDP to Net Export increases gradually, reaching 20.32% in the tenth period. In comparison, Net Export's contribution decreases to 79.68%. This pattern reflects the dynamic relationship between the two variables, in which the role of GRDP becomes increasingly significant over time.

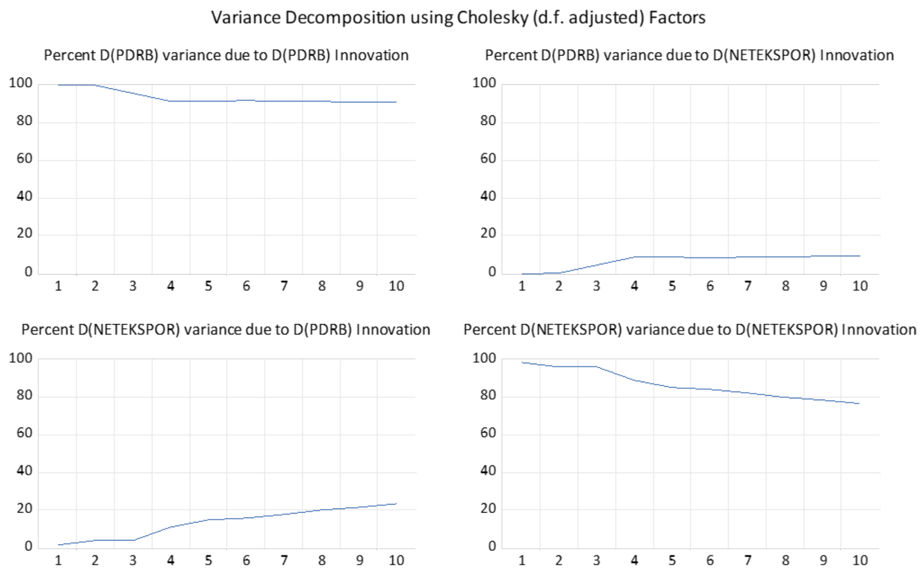

Figure 3. Variance Decomposition (VD) Plot Results

Figure 3 shows that changes in Net Exports (D(NETEXPOR)) are largely influenced by innovation in itself, with almost 100% of the variation explained by internal factors at the beginning of the period. Over time, the innovation effect of GRDP (D(GRDP)) increases slowly to around 10% in the 10th period. This suggests that in the short term, changes in Net Export are more influenced by internal factors such as trade or export-import policies, while in the long term, external factors such as GRDP start to make a larger contribution, although it remains relatively small compared to the internal influence.

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D. CONCLUSION AND SUGGESTION

The conclution for this research is show In the long run, with PVECM the relationship between Net Export and GRDP shows a negative and significant effect, where every 1 unit increase in Net Export will decrease GRDP by 5.445139 units. This indicates that even though Net Export increases, it may reflect a decrease in domestic economic activity, such as consumption or investment, which in turn has an impact on GRDP. GRDP in the previous two-year period has a significant effect on Indonesias Net Export and Net Export in the previous two-year period has a significant effect on GRDP in Indonesia. These results indicate a two-way relationship between the Net Export and GRDP variables in Indonesia.

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DECLARATIONS

AUTHOR CONTIBUTION

In this study, first author contributed as a writer, conducted the data analysis. The second author provides research topic ideas and made revisions to the reviewer suggestions. The third author provides the research topic ideas and undertake data interpretation. The four author prepared the initial draft and assisted in collecting data.

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COMPETING INTEREST

The authors firmly assert that there is no conflict of interest in this article.

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