Investigating the Export-Growth Nexus: The Case of Japan

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Abstract

Japan's economy is traditionally marked by a strong export-oriented industrial structure, particularly within the manufacturing sector, which encompasses industries classified under "export core manufacturing." This paper examines the short-run and long-run relationships between exports and GDP in Japan, investigating the potential for bi-directional causality, commonly referred to as the feedback effect. To achieve this, we employed a Vector Error Correction Model (VECM), Granger Causality Test, and Impulse Response Function (IRF), and extended our analysis using a Variance Decomposition Analysis. Our results indicate no evidence of a feedback effect; specifically, exports do not predict GDP in the long run. However, we found significant causal evidence indicating that GDP influences exports, suggesting that export growth in Japan is driven by economic growth, consistent with existing literature.

Keywords: Export-Driven Growth, Growth-Driven Export, Japanese Economy, VECM, Bi-directional Granger Causality, Feedback Effect

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1 Introduction

Japan's economy has long been characterized by its export-oriented industrial structure, which has played a role in the nation's post-war economic recovery and growth. Historically, as Zukhra and Kamilova (2024) point out, Japan has maintained a positive trade balance, exporting more goods and services than it imports, a trend that has fueled its economic strength. In recent decades, however, Japan has experienced significant economic restructuring, phasing out energy- and material-intensive industries and placing more emphasis on technological innovation and efficiency.

Despite this shift, exports continued to play a critical role, particularly in the manufacturing sector. Industries classified under "export-core manufacturing," such as transportation equipment, machinery, and electronics, maintained high export-output ratios between 1980 and 2008 (Uemura and Tahara, 2014). These industries demonstrated a strong response to fluctuations in global demand, highlighting the interconnectedness of Japan's economy with global markets. However, Japan's export performance has faced increasing challenges due to intensifying competition from emerging economies, especially China, which has eroded Japan's competitive advantage in some sectors (Hogen *et al.*, 2024).

Japan's trade dynamics extends beyond historical interest, as it speaks directly to contemporary debates in finance and economics. In particular, understanding the relationship between exports and gross domestic product (GDP) is essential for evaluating the impact of trade on national economic growth. Japan, a leading investor globally, continues to be a significant player in the development of global value chains (Wang *et al.*, 2021). However, the country now faces challenges, including declining competitiveness in key sectors, intensifying global competition, and currency depreciation (Hogen *et al.*, 2024). These developments make it increasingly important to analyze how exports and GDP interact, not only in Japan's economy but also in the context of global financial flows and trade agreements.

In this research paper, we analyze the short-run and long-run relationships between exports and GDP in Japan and investigate the possible existence of bi-directional causality between the two variables, also known as the feedback effect. The existence of a bidirectional causality suggests the existence of a feedback effect: not only can exports lead to economic growth through increased production and trade revenues, but economic growth can also enhance export capacity by raising productivity and creating a more competitive industrial base.

The potential bidirectional relationship between exports and GDP has been a subject of debate. One stream of research supports the traditional view that exports are a driver of economic growth, citing channels such as the "R&D channel" where firms engage in research and development to enhance competitiveness in international markets (Trefler, 2004). This is particularly relevant in Japan, where firms have historically improved production efficiency through innovations, such as process innovations that reduce costs (Hogen *et al.*, 2024). Additionally, exports contribute to productivity growth through access to cheaper intermediate goods, as seen in Japan's reliance on low-cost inputs from East Asia, which lowered production costs and boosted competitiveness in downstream sectors (Fabinger *et al.*, 2017).

Conversely, there is evidence to suggest that economic growth itself can drive export expansion. As domestic industries grow and diversify, they may seek new markets abroad to maintain growth, a pattern observed in Japan's transition from an export-driven economy to one characterized by domestic consumption in the 1980s (Zukhra and Kamilova, 2024). Japanese firms, facing stagnating domestic demand and a declining population, have increasingly turned to foreign markets to sustain growth (Nishiguchi (2021), as cited in Hogen *et al.*, (2024)). The "knowledge spillover channel" further suggests that firms involved in international trade benefit from exposure to foreign innovations, which can enhance their competitive edge and spur economic growth (Grossman and Helpman, 1991).

Exports are a key driver of GDP growth, not just for Japan, but also for many economies, and understanding how they interact can provide insights into global trade patterns, investment flows, and the implications for financial markets. Moreover, given Japan's leadership in high-tech and value-added industries (Podoba *et al.*, 2021), the findings of this study could inform policy recommendations on trade, industrial strategy, and financial management for both developed and developing countries. Thus, this research contributes to the understanding of export-led growth models and their significance in shaping economic policy and international finance.

2 Data and Methodology

2.1 Data

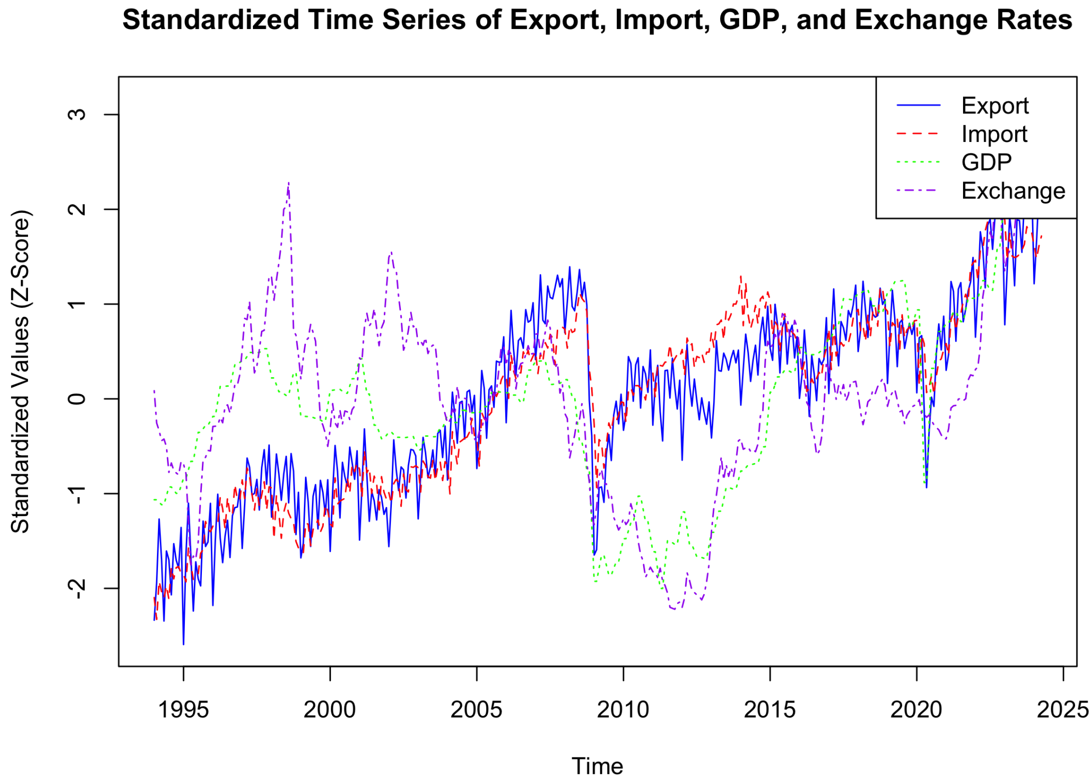
The dataset used in this study comprises several key economic indicators for Japan, focusing on Gross Domestic Product (GDP), exchange rates, exports, and imports. The GDP data is measured in Japanese yen on a quarterly basis, and for analytical consistency, it was interpolated to a monthly frequency. The Japanese yen to U.S. dollar spot exchange rate is provided on a monthly basis, representing the relative currency value between Japan and the United States. Monthly data on Japan's total exports and imports was also incorporated to capture trade dynamics.

The Japanese GDP and the yen to U.S. dollar exchange rate were obtained from the Federal Reserve Economic Data (FRED) database, ensuring reliable and consistent historical data. Meanwhile, Japan's total exports and imports data were sourced from the Bank of Japan. To standardize the analysis, all time series—except for the exchange rate—were transformed using the natural logarithmic form. This transformation mitigates heteroscedasticity and allows for an analysis of growth rates rather than absolute levels, facilitating a clearer interpretation of trends and relationships among the variables.

Figure 1 illustrate the time series trends for exports, imports, GDP, and exchange rates from the early 1990s to 2025, using their standardized z-scores, allowing for a direct comparison of relative fluctuations around each variable's mean and highlighting temporal trends and volatility in the economic indicators in question, irrespective of their original scales. to allow direct comparisons.

Exports and imports show similar upward trends, especially after 2000, indicating strong growth in international trade. These trade variables exhibit periodic fluctuations, with exports generally

Figure 1: Standardized Z-Score Values of the Variables of Interest



leading imports in terms of higher peaks. The increasing alignment of exports and imports over time suggests balanced trade dynamics, likely supported by favorable trade policies or economic conditions.

GDP, while less volatile than the trade variables, displays a steady upward trend, particularly pronounced after the 2008 financial crisis and the COVID-19-related dip around 2020. The overall growth in GDP aligns with increases in exports and imports, indicating that international trade may contribute positively to economic expansion. The stability of GDP relative to the other indicators underscores its role as a broader economic measure, influenced by both domestic activities and international trade.

The exchange rate exhibits substantial volatility in the early years, which may reflect economic uncertainty or currency instability. However, after 2010, the exchange rate trend stabilizes, coinciding with a more predictable environment for trade and economic growth. This stability likely supports the upward trends in exports and imports post-2010, suggesting that a stable currency environment benefits trade. Together, these indicators suggest that, by 2025, the economy is in a phase of expansion with strong trade performance and a stabilized exchange rate, fostering an environment conducive to sustained growth.

2.2 Methodology

To investigate the stationarity properties of the time series, we conduct a univariate analysis of each of the four time series, which includes GDP, exports, imports, and exchange rates. To test for the presence of a unit root, we employ the Augmented Dickey-Fuller (ADF) test, as follows:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t \tag{1}$$

where:

- Y_t is one of the time series (GDP, Total Exports, Total Imports, or Exchange Rates),
- α is the intercept,
- βt is the deterministic trend,
- γY_{t-1} tests for the presence of a unit root, where $\gamma = 0$ under the null hypothesis (non-stationary series),
- $\sum_{i=1}^{p} \delta_i \Delta Y_{t-i}$ includes lagged differences to address autocorrelation,
- ε_t is the error term.

The null hypothesis of the ADF test is that the series contains a unit root, which implies non-stationarity at levels. For each of the original series, the ADF test indicate the presence of a unit root, which implies that none of the variables represents a stationary process. To address this, we detrend the series by taking the first differences, transforming them into stationary time series to ensure that the models are appropriately specified for further econometric analysis.

Initially, before specifying a Vector Error Correction model (VECM), we devise a Vector Autoregressive (VAR) model to determine the optimal number of lags to be used for the VECM. The optimal number of lags was determined through various lag-selection criteria which can be implemented through a VAR model, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Hannan-Quinn Information Criterion (HQIC), and Final Prediction Error (FPE). Based on these criteria, the optimal lag length was determined to be three.

Cointegration between variables constrains the use of a simple VAR model because cointegrated variables share a long-run equilibrium relationship (Johansen, 1988). In this regard, we conduct a Johansen cointegration test to assess whether GDP, exports, imports, and exchange rates are cointegrated:

$$\Delta Z_t = \mathbf{\Pi} Z_{t-1} + \sum_{i=1}^{p-1} \mathbf{\Gamma}_i \Delta Z_{t-i} + \varepsilon_t \tag{2}$$

where:

- Z_t is a vector of the variables GDP, Exports, Imports, and Exchange Rates indexed at time t,
- $\mathbf{\Pi} = \alpha\beta'$, where
  - α represents adjustment coefficients (how quickly deviations from equilibrium are corrected),
  - β contains cointegrating vectors (the long-term equilibrium relationships),
- $\mathbf{\Gamma}_i$ are short-run adjustment coefficients,
- ε_t is the error term.

The presence of cointegration would indicate that the two variables move together in the long run, despite short-term fluctuations. If the test suggests that there is no cointegration between the variables, we proceed with the estimation of the VAR model. If, otherwise, cointegration is detected, the VAR model would be inappropriate for capturing the long-term relationship between the variables. In such a case, we specify a Vector Error Correction Model (VECM), which incorporates both short-term dynamics and long-term equilibrium relationships between the variables. Based on the Johansen cointegration test, we find a presence of cointegration between the variables and proceed to estimate a VECM to capture the both short-run dynamics and long-run equilibrium relationships, as follows:

$$\Delta Y_t = \alpha(\beta' Z_{t-1}) + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \tag{3}$$

where:

- ΔY_t is a vector of the variables ΔGDP_t, $\Delta Exports_t$, $\Delta Imports_t$, and $\Delta ExchangeRates_t$,
- $\alpha(\beta' Z_{t-1})$ is the error correction term, with α representing the speed of adjustment toward the long-run equilibrium,
- β contains cointegrating relationships among the variables,
- $\sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i}$ represents the short-term effects of the variables on one another,
- ε_t is the error term.

The error correction term $\alpha(\beta' Z_{t-1})$ shows the extent to which deviations from equilibrium in one period are corrected in the subsequent period, allowing us to interpret both long-term and short-term causality among Japan's GDP, exports, imports, and exchange rate.

One of the key objectives in our paper is to investigate the existence of a feedback effect that may describe the export-growth nexus in the Japanese economy, which can be detected through a bi-directional Granger causality test. To explore such relationships between GDP and exports, we perform a Granger causality test to determine whether past values of exports can help predict GDP, or vice versa, beyond the information contained in their own past values. Since the Johansen test reveals cointegration between GDP and exports, we perform a bi-directional Granger causality test in the context of a VECM. In this case, the interpretation of the causality test can be extended to both the short-run and long-run relationships between the variables. [1] If exports Granger-cause GDP, it suggests that exports are a significant driver of economic growth. Conversely, if GDP Granger-causes exports, economic growth is a critical factor in enhancing export performance.

Additionally, we employ an impulse response function (IRF) to assess the dynamic effects of shocks to one variable on another over time. The IRF traces the response of a variable (e.g., GDP) to a one-unit shock in another variable (e.g., exports) within the context of the VECM model to reflect how GDP responds to an unexpected change in exports and vice versa, shedding light on the short-term and long-term impacts of such shocks (Sims, 1980). The impulse response analysis complements the Granger causality test by offering a more detailed view of the temporal relationships between the variables and quantifying the magnitude and duration of the effects of shocks.

3 Results

3.1 Unit Root Test

In order to investigate the stationarity properties of the data, a univariate analysis of each of the four time series GDP, exports, imports, and exchange rates was carried out by testing for the presence of a unit root using an Augmented Dickey-Fuller (ADF) t-test. Initially, at conventional levels of significance, none of the variables cross different ADF test specifications represents a stationary process (See Appendix A). After detrending each time series, we find that the results of the Augmented Dickey-Fuller (ADF) tests indicate stationarity for each variables. For each series, the ADF test statistic is compared against critical values at the 1%, 5%, and 10% levels. The results indicate statistically significant results (p-value < 0.05) for all time series for different specifications, which motivates the rejection of the null hypothesis of a unit root, suggesting that the series no longer exhibit unit roots and have constant statistical properties over time. As differencing once produces stationarity, we conclude that each of the series is integrated in order 1, (I)1 (See Table I).

[1] If no cointegration is found, the Granger causality test was performed using the standard VAR model. In this scenario, the interpretation of causality is limited to short-run relationships.

Table I: ADF Test Results for the Time Series Variables after Differencing

ADF Test Results for GDP							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-0.474	-6.560	0.000	4	-3.984	-3.423	-3.134
Constant	-0.000	-0.346	0.729				
Trend	0.000	1.039	0.300				
Constant Only	-0.465	-6.480	0.000	4	-3.449	-2.870	-2.571
Constant	0.000	1.089	0.277				
No Constant	-0.452	-6.387	0.000	4	-2.572	-1.942	-1.616
ADF Test Results for Total Exports							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-1.820	-6.798	0.000	14	-3.985	-3.423	-3.135
Constant	0.005	0.832	0.406				
Trend	0.000	0.021	0.983				
Constant Only	-1.820	-6.808	0.000	14	-3.449	-2.870	-2.571
Constant	0.005	1.669	0.096				
No Constant	-1.712	-6.583	0.000	14	-2.572	-1.942	-1.616
ADF Test Results for Total Imports							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-1.421	-5.689	0.000	14	-3.985	-3.423	-3.135
Constant	0.006	0.949	0.343				
Trend	-0.000	-0.098	0.922				
Constant Only	-1.420	-5.699	0.000	14	-3.449	-2.870	-2.571
Constant	0.005	1.689	0.092				
No Constant	-1.294	-5.428	0.000	14	-2.572	-1.942	-1.616
ADF Test Results for Exchange Rates							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-0.708	-14.049	0.000	0	-3.984	-3.423	-3.134
Constant	-0.132	-0.468	0.640				
Trend	0.001	0.951	0.342				
Constant Only	-0.704	-14.019	0.000	0	-3.449	-2.870	-2.571
Constant	0.100	0.714	0.476				
No Constant	-0.703	-14.011	0.000	0	-2.572	-1.942	-1.616

3.2 Selection Criterion

Prior to performing the cointegration test, we determine the order of the VAR using the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), the Final Prediction Error (FPE), and the Hannan-Quinn Information Criterion (HQIC) to determine the number of lags to be used for cointegration test (See Table II). The minimum value for AIC occurs at lag 10 (-20.49), indicating that AIC prefers a model with the longest evaluated lag length. BIC reaches its minimum at lag 3 (-19.50). Similar to the AIC, FPE finds its minimum at lag 10 (1.263e-09). HQIC, known to provide a more conservative lag selection than AIC, records its minimum at lag 6 (-19.93).

We use, in this paper, the optimal lag value determined by the BIC. Given BIC's penalty on the number of parameters, it often favors simpler models, potentially sacrificing some degree of fit

Table II: VAR Order Selection (* highlights the minimums)

Lag	AIC	BIC	FPE	HQIC
0	-8.843	-8.799	0.0001444	-8.825
1	-18.64	-18.42	8.040e-09	-18.55
2	-19.57	-19.18	3.153e-09	-19.42
3	-20.07	**-19.50***	1.929e-09	-19.84
4	-20.18	-19.44	1.715e-09	-19.89
5	-20.29	-19.37	1.540e-09	-19.93
6	-20.37	-19.27	1.431e-09	**-19.93***
7	-20.37	-19.10	1.427e-09	-19.86
8	-20.34	-18.90	1.467e-09	-19.77
9	-20.34	-18.73	1.464e-09	-19.70
10	**-20.49***	-18.70	**1.263e-09***	-19.78

to avoid overfitting. AIC and FPE, on the other hand, favors a more complex model, likely due to its tendency to select models that may better capture short-term dynamics by minimizing forecast error, albeit sometimes at the risk of overfitting.

3.3 Johansen Cointegration Test

In the results of the Johansen cointegration test, we reject the null hypothesis of no cointegration up to $r \leq 1$, which indicates that there are at least two cointegrating relationships among the variables GDP, real exchange rate, total exports, and total imports (See Table III). This finding suggests that the variables share long-term equilibrium relationships, implying that despite short-term fluctuations, they are connected in the long run and tend to move together over time.

Table III: Johansen Cointegration Test Results

r	Eigenvalue Test Statistic	90%	95%	99%
0	147.700023	44.4929	47.8545	54.6815
1	34.533847	27.0669	29.7961	35.4628
2	7.683073	13.4294	15.4943	19.9349
3	0.944970	2.7055	3.8415	6.6349

Given the presence of cointegration, we proceed by specifying a Vector Error Correction Model (VECM) instead of a Vector Autoregressive (VAR) model. The reason for this adjustment is that in the presence of cointegration, the VAR model, which assumes that the variables are stationary, is no longer appropriate. A VECM, as discussed by Johansen (1988), is essentially a restricted VAR model that incorporates the cointegrating relationships, allowing for both long-run equilibrium and short-term dynamics. The VECM adjusts for deviations from long-term equilibrium, thus capturing the error correction mechanism that brings the variables back into equilibrium when they diverge in the short run.

Since the rank of cointegration is 2, that is, there are two long-term relationships, the VECM will include two error correction terms. These terms measure the speed at which the variables return to equilibrium after a disturbance. Additionally, based on the lag selection criteria (such as AIC, BIC, HQIC, or FPE), the optimal number of lags for the model is determined to be 3, ensuring that the model adequately captures the dynamics between the variables without overfitting or underfitting.

3.4 Vector Error Correction Model

Based on the results of the VECM, the estimated cointegration vectors (β coefficients) reveal long-term relationships among the variables (See Table IV). Specifically, the coefficients from the first cointegration relation suggest a negative relationship between GDP and total imports (β_3 = -0.8159) indicating that an increase in imports tends to exert downward pressure on GDP in the long run. The significant z-statistic for this coefficient (-6.864) affirms its statistical relevance. The second cointegration relation highlights a strong positive correlation between the real exchange rate and total exports (β_4 = 0.5118), which suggests that higher exports are associated with higher real exchange rates in the long term. The substantial coefficient (190.4934) underscores the potential for exports to significantly influence the real exchange rate over time, reflecting a positive dynamic in the export sector that can stimulate economic activity.

Table IV: Cointegration Relations for All Loading Coefficients

A. Cointegration Relations for the Loading Coefficient α_1					
	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
β_1	1.0000	0	0	0.000	[1.000, 1.000]
β_2	-1.82e-18	0	0	0.000	[-1.82e-18, -1.82e-18]
β_3	-0.8159	0.119	-6.864	0.000	[-1.049, -0.583]
β_4	0.5118	35.469	0.014	0.988	[-69.006, 70.030]
const	-9.4344	0.080	-117.854	0.000	[-9.591, -9.278]
B. Cointegration Relations for the Loading Coefficient α_2					
	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
β_1	9.969e-15	0	0	0.000	[9.97e-15, 9.97e-15]
β_2	1.0000	0	0	0.000	[1.000, 1.000]
β_3	-284.1682	23.885	-11.897	0.000	[-330.983, -237.354]
β_4	190.4934	0.405	469.812	0.000	[189.699, 191.288]
const	707.8533	120.981	5.851	0.000	[470.734, 944.972]

The loading coefficients (α coefficients) indicates the short-run adjustments towards the long-term equilibrium (See Table V). For the GDP equation, the error correction terms from the first cointegration relation (α_1 = -0.0033) are not statistically significant, suggesting that GDP does not rapidly return to equilibrium after deviations. However, the second error correction term (α_2 = 5.53e-05) is significant (p = 0.016), indicating a slow but statistically relevant adjustment mechanism. In the real exchange rate equation, the first cointegration error correction term (α_1 = 26.9391) is highly significant ($p < 0.001$), suggesting a strong short-term response to deviations from long-term equilibrium. The negative coefficient of the second error correction term (α_2 = -0.0553) indicates that as the system deviates from equilibrium, the real exchange rate adjusts negatively, reinforcing its return to equilibrium. For the exports equation, the first error correction term (α_1 = 0.1513) is not statistically significant, indicating limited short-term adjustment. The second term (α_2 = -3.675e-05) is not significant as well, suggesting that short-term dynamics for total exports may not substantially influence the long-term relationship. Lastly, in the imports equation, the first error correction term (α_1 = 0.2262) is significant (p = 0.031), indicating that imports adjust to restore equilibrium when deviations occur. The second term (α_2 = -0.0012) is negative and significant, which implies that any disequilibrium prompts an adjustment in the opposite direction, thus contributing to equilibrium restoration.

Table V: Loading Coefficients for All Equations

Equation	Variable	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
GDP	α_1	-0.0033	0.009	-0.387	0.699	[-0.020, 0.013]
	α_2	5.53e-05	2.29e-05	2.412	0.016	[1.04e-05, 0.000]
Exchange Rate	α_1	26.9391	5.591	4.818	0.000	[15.981, 37.898]
	α_2	-0.0553	0.015	-3.673	0.000	[-0.085, -0.026]
Total Exports	α_1	0.1513	0.175	0.864	0.387	[-0.192, 0.494]
	α_2	-3.675e-05	0.000	-0.078	0.938	[-0.001, 0.001]
Total Imports	α_1	0.2262	0.105	2.160	0.031	[0.021, 0.431]
	α_2	-0.0012	0.000	-4.414	0.000	[-0.002, -0.001]

3.5 Extension: Variance Decomposition Analysis

Variance decomposition provides insights into the relative contributions of different shocks to the forecast error variance of each endogenous variable in the Vector Error Correction Model (VECM). The analysis helps reveal how much of the variability in each variable is explained by shocks to itself versus shocks to other variables. For instance, understanding how much of GDP's fluctuations are due to changes in exchange rates or export volumes can clarify how different economic forces shape economic output. Moreover, economic variables like GDP, imports, exports, and exchange rates are often interlinked, and variance decomposition helps quantify these interdependencies. For example, if a large portion of GDP variance is driven by imports, it indicates a strong dependency of the domestic economy on foreign goods, potentially shaping policy discussions on trade and tariffs.

The variance decomposition for GDP reveals that initial shocks are overwhelmingly explained by its own past values, reflecting a high degree of persistence (See Table VI. For instance, in the first period, 100% of the variance is attributed to GDP itself. However, as we progress through subsequent periods, the influence of other variables becomes more pronounced. By the tenth period, the share of the variance explained by GDP declines to approximately 84.82%, while the contributions from other variables, particularly total imports (about 10.12%), start to emerge. This pattern suggests that while GDP retains its dominance in explaining its own variance, external influences such as imports begin to play a more significant role over time.

Similarly, the variance decomposition results for total exports highlight dependency on past values of itself and other variables. In the first period, approximately 98.35% of the variance in total exports is explained by its own past values, with a very small share from GDP (1.46%). However, as we observe the decomposition over ten periods, it is evident that the influence of total

Table VI: Results of the Variance Decomposition in a 10-Month Horizon

Variance Decomposition for GDP				
Horizon	GDP	Exchange Rates	Total Exports	Total Imports
1	1.0000	0.0000	0.0000	0.0000
2	0.9889	0.0009	0.0003	0.0099
3	0.9644	0.0048	0.0012	0.0295
4	0.9433	0.0096	0.0012	0.0459
5	0.9268	0.0140	0.0013	0.0579
6	0.9114	0.0185	0.0031	0.0670
7	0.8950	0.0227	0.0066	0.0756
8	0.8786	0.0264	0.0101	0.0849
9	0.8630	0.0293	0.0142	0.0936
10	0.8482	0.0313	0.0192	0.1012

Variance Decomposition for Exchange Rates				
Horizon	GDP	Exchange Rates	Total Exports	Total Imports
1	0.0013	0.9987	0.0000	0.0000
2	0.0018	0.9946	0.0036	0.0000
3	0.0021	0.9880	0.0091	0.0008
4	0.0020	0.9775	0.0194	0.0011
5	0.0021	0.9642	0.0318	0.0019
6	0.0027	0.9522	0.0417	0.0033
7	0.0041	0.9378	0.0533	0.0048
8	0.0067	0.9206	0.0659	0.0068
9	0.0105	0.9035	0.0765	0.0094
10	0.0155	0.8852	0.0870	0.0124

Variance Decomposition for Total Exports				
Horizon	GDP	Exchange Rates	Total Exports	Total Imports
1	0.0146	0.0019	0.9835	0.0000
2	0.0338	0.0391	0.9205	0.0065
3	0.0919	0.0713	0.8310	0.0059
4	0.1365	0.0767	0.7702	0.0165
5	0.1407	0.0944	0.7405	0.0244
6	0.1528	0.1098	0.7100	0.0273
7	0.1693	0.1115	0.6836	0.0355
8	0.1780	0.1139	0.6657	0.0424
9	0.1877	0.1178	0.6459	0.0486
10	0.1979	0.1170	0.6286	0.0565

Variance Decomposition for Total Imports				
Horizon	GDP	Exchange Rates	Total Exports	Total Imports
1	0.0118	0.0244	0.1486	0.8152
2	0.0132	0.1210	0.4683	0.3976
3	0.0348	0.1592	0.4083	0.3977
4	0.0567	0.1699	0.3963	0.3771
5	0.0696	0.1788	0.4130	0.3386
6	0.0826	0.1767	0.3968	0.3439
7	0.0973	0.1686	0.3950	0.3391
8	0.1123	0.1574	0.3957	0.3345
9	0.1266	0.1466	0.3906	0.3362
10	0.1408	0.1359	0.3876	0.3357

imports grows substantially, rising to around 64.59% by the tenth period, while the influence of GDP decreases (to about 19.79%).

The results of the variance decomposition analysis also highlight the interconnectedness between total exports and imports in that fluctuations in imports can influence export performance over time. For total imports, the initial periods indicate that shocks to total imports are significantly influenced by their own past values (81.52% in the first period). However, this influence diminishes over time, as the contributions from total exports and GDP increase. By the tenth period, total imports are influenced by their own past values (33.57%), while total exports contribute about 38.76%, and GDP's contribution remains around 14.41%. The results suggest a dynamic trend indicating the role of exports and GDP in determining import levels.

The insights from the variance decomposition align well with the VECM results. The long-term relationships identified in the VECM, particularly the significant coefficients for lagged GDP and imports in the GDP equation, reinforce the notion that these variables play crucial roles in shaping economic outcomes. The variance decomposition supports the finding that GDP, in itself, is a key driver of economic activity in that, the past values of GDP determines the value of GDP today, yet also indicates a growing importance of imports over time.

The strong and statistically significant loading coefficients for exchange rates in the VECM suggest that exchange rate dynamics play a central role in shaping economic expectations. This is further supported by the high degree of stability observed in the variance decomposition for exchange rates, indicating that exchange rate fluctuations, including monetary policy that influences exchange rate dynamics both from the country in itself and internationally, are the primary drivers affecting economic expectations. The interdependencies revealed in the variance decomposition further highlight the importance of considering external shocks and their cascading effects through the economy.

3.6 Granger Causality Test

The Granger causality tests were conducted to examine the relationship between Gross Domestic Product and total exports across three different lag lengths: 1, 2, and 3 (See Table VII). The objective was to determine if past values of exports can help predict current values of GDP, thereby establishing a causal link. The results of the Granger causality tests across lags 1, 2, and 3 demonstrate a clear lack of predictive power of total exports on GDP. For all model specifications, the p-values are very high, indicating a lack of statistically significant causality between exports and GDP. The F-test and chi-squared test p-values are also above the conventional significance level of 0.05, indicating that past values of exports do not influence GDP, consistent with findings from the previous lag lengths. Hence, we fail to reject the null hypothesis, reaffirming that past export values do not provide predictive power for GDP at this lag length. The consistently high p-values suggest that there is no statistically significant relationship between these two variables in the studied timeframe. This finding implies that while GDP and exports may be related in the long term, the changes in exports do not appear to cause changes in GDP in the short to medium term, as indicated by the lack of Granger causality.

Table VII: Bi-directional Causality Test for Total Exports and GDP

A. Granger Causality Test from GDP to Total Exports				
Number of Lags	Test	Statistic	p-value	df
1	SSR based F test	$F = 6.9220$	0.0089	(360, 1)
	SSR based χ^2 test	$\chi^2 = 6.9797$	0.0082	1
	Likelihood ratio test	$\chi^2 = 6.9134$	0.0086	1
	Parameter F test	$F = 6.9220$	0.0089	(360, 1)
2	SSR based F test	$F = 5.3835$	0.0050	(357, 2)
	SSR based χ^2 test	$\chi^2 = 10.9179$	0.0043	2
	Likelihood ratio test	$\chi^2 = 10.7565$	0.0046	2
	Parameter F test	$F = 5.3835$	0.0050	(357, 2)
3	SSR based F test	$F = 12.0314$	0.0000	(354, 3)
	SSR based χ^2 test	$\chi^2 = 36.8080$	0.0000	3
	Likelihood ratio test	$\chi^2 = 35.0500$	0.0000	3
	Parameter F test	$F = 12.0314$	0.0000	(354, 3)

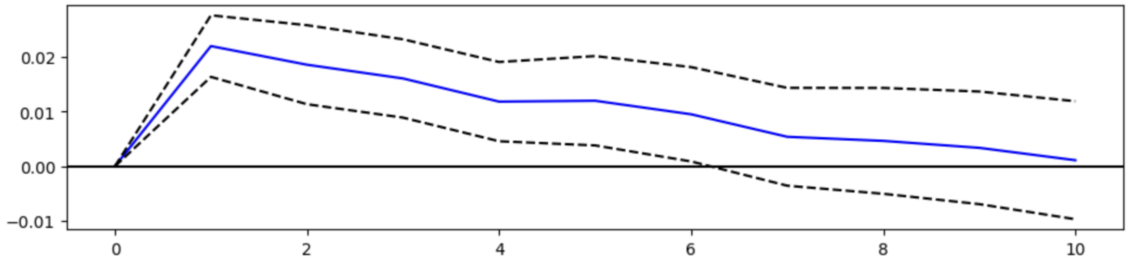
B. Granger Causality Test from Total Exports to GDP				
Number of Lags	Test	Statistic	p-value	df
1	SSR based F test	$F = 0.0014$	0.9700	(360, 1)
	SSR based χ^2 test	$\chi^2 = 0.0014$	0.9699	1
	Likelihood ratio test	$\chi^2 = 0.0014$	0.9699	1
	Parameter F test	$F = 0.0014$	0.9700	(360, 1)
2	SSR based F test	$F = 0.0063$	0.9938	(357, 2)
	SSR based χ^2 test	$\chi^2 = 0.0127$	0.9937	2
	Likelihood ratio test	$\chi^2 = 0.0127$	0.9937	2
	Parameter F test	$F = 0.0063$	0.9938	(357, 2)
3	SSR based F test	$F = 0.3599$	0.7820	(354, 3)
	SSR based χ^2 test	$\chi^2 = 1.1010$	0.7768	3
	Likelihood ratio test	$\chi^2 = 1.0994$	0.7772	3
	Parameter F test	$F = 0.3599$	0.7820	(354, 3)

Next, we run a Granger causality test to determine if past values of GDP can help predict current values of exports. For a lag of 1 period, the results indicate a statistically significant relationship between total exports and GDP. Both the F-test and chi-squared test yield p-values below the conventional significance level of 0.05, allowing us to reject the null hypothesis. This suggests that total exports Granger-cause GDP at this lag length. At a lag of 2 periods, the results continue to support the hypothesis of Granger causality. The p-values remain significantly below 0.05, indicating a strong relationship between past values of exports and current GDP values. This further reinforces the conclusion that total exports have predictive power over GDP in the short to medium term. At the 3-period lag, the evidence for Granger causality is even more pronounced. The F-test and chi-squared test results indicate extremely low p-values, well below the significance threshold. This strong evidence allows us to confidently reject the null hypothesis, confirming that total exports Granger-cause GDP at this lag length. Hence, the Granger causality tests across lag lengths of 1, 2, and 3 demonstrate a robust and statistically significant causal relationship from total exports to GDP. The consistent pattern of significant p-values suggests that changes in exports can be used to predict changes in GDP, supporting the GDP-driven export which implies that export activity in Japan plays a crucial role in influencing economic activity.

3.7 Impulse Response Function

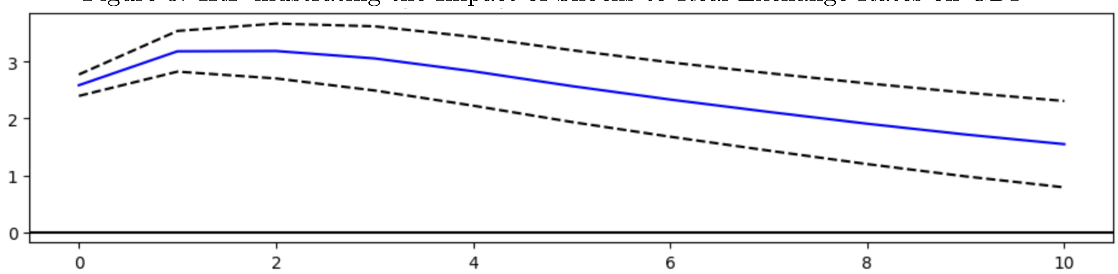
Figure 2 demonstrates the dynamic effects of a one-time shock to total imports on GDP over time. Iinitially, the IRF shows a sharp positive response of GDP to the import shock, suggesting that imports stimulate economic activity, potentially due to increased consumption or investment fueled by imported goods. This initial surge reflects an overshooting effect, with GDP rising above its long-run level. Such an overshoot implies that while the initial stimulus from imports is substantial, it is followed by an adjustment period as the economy reverts to equilibrium. The IRF displays a monotonic decline back to zero, indicating that the positive impact of the import shock gradually dissipates over time. The speed of this decline reveals the shock's persistence, providing insight into the duration of its effects on economic activity.

Figure 2: IRF illustrating the Impact of Shocks to Total Imports on GDP



Imports can influence aggregate demand directly by increasing household and firm consumption or investment in imported goods. However, if the shock is transitory, the initial demand boost may be followed by a contraction as households and firms adjust spending back toward domestic products. Imports also affect the supply side by providing intermediate inputs or capital goods, potentially raising productivity and output in the short term. Nevertheless, a negative shock to imports could disrupt supply chains and lead to higher production costs, thereby dampening long-term economic activity.

Figure 3: IRF illustrating the Impact of Shocks to Real Exchange Rates on GDP



The dynamic impact of a one-time shock to the real exchange rate on GDP, particularly focusing on how a depreciation of the domestic currency affects economic activity, is shown in Figure 3. Initially, the IRF reveals a sharp positive response, as a depreciation boosts GDP by enhancing net exports; domestic goods become relatively cheaper for foreign consumers, increasing export demand. However, this effect overshoots, with GDP rising above its long-run level, indicating that the initial stimulus might be followed by a dampening adjustment. The IRF's monotonic decline back to zero implies that the positive impact of the exchange rate shock fades over time, with the rate of this decline shedding light on the shock's persistence.

A depreciation enhances aggregate demand by increasing net exports, which supports output, employment, and investment. If the exchange rate shock is temporary, this stimulus may be followed by a contraction as the currency appreciates and net exports decrease. Exchange rate fluctuations also impact the supply side, as changes in the relative prices of imported inputs can affect production costs and firm profitability. A persistent depreciation could lead to higher production costs, dampening economic activity in the long term if firms face elevated expenses for imported intermediate goods.

Figure 4: IRF illustrating the Impact of Shocks to Total Exports on GDP

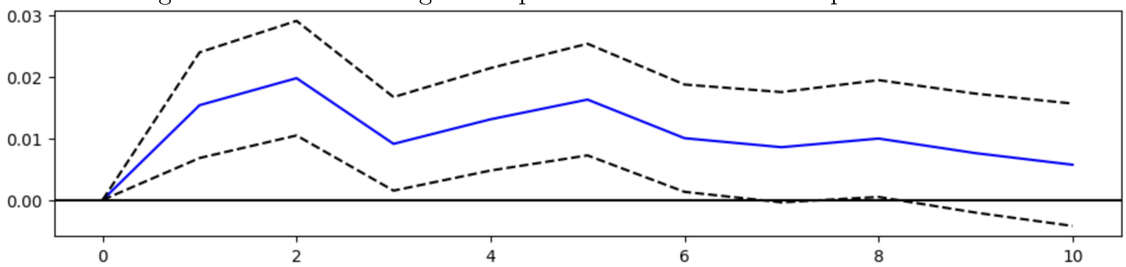


Figure 4 illustrates the dynamic impact of a one-time shock to total exports on GDP over time. Following an export shock, GDP exhibits a sharp positive response, indicating that exports initially stimulate economic activity by boosting demand for domestic goods and services in foreign markets. This response also overshoots, with GDP rising above its long-run equilibrium, suggesting a strong immediate impact followed by an adjustment phase. After this overshooting, the IRF shows a gradual decline to zero, signifying that the export shock's effect dissipates over time. The rate of this decline can reveal the persistence of export-driven economic growth.

Exports directly boost aggregate demand, as increased foreign demand can lead to higher domestic output, employment, and investment. However, if the export shock is temporary, the initial stimulus may be followed by a downturn if foreign demand diminishes. On the supply side, export shocks can incentivize firms to invest in productivity-enhancing technologies, which supports long-term output growth. Conversely, a negative export shock could disincentivize investment, potentially leading to a slowdown in productivity gains.

4 Discussion

The intricate interplay between exports and GDP in Japan's economy has been the subject of extensive scholarly analysis, particularly in the context of export-led growth models and the dynamic relationships that exist between these critical economic variables. This study aims to analyze the short-run and long-run relationships between exports and GDP while investigating the potential for bi-directional causality, which supports a feedback effect between export-led growth and growth-driven exports.

The findings from the Vector Error Correction Model (VECM) reveal that GDP, total exports, total imports, and the real exchange rate maintain long-term equilibrium relationships, indicating that these variables are interconnected despite short-term fluctuations. This is consistent with the literature that underscores the importance of trade and economic growth. For instance, as Zukhra and Kamilova (2024) highlight, Japan has historically maintained a positive trade balance, which has been instrumental in driving economic strength. The negative relationship found between GDP and total imports (β_3 = -0.8159) suggests that increased imports exert downward pressure on GDP in the long run. This finding resonates with the view that while imports can offer competitive advantages and lower consumer prices, excessive reliance on foreign goods can detract from domestic production and growth.

Furthermore, the analysis points to a strong positive correlation between the real exchange rate and total exports ($beta_4 = 0.5118$). This suggests that as exports increase, they can significantly influence the real exchange rate, aligning with previous studies that emphasize the role of exports in enhancing a country's economic standing in global markets. Notably, Uemura and Tahara (2014) have indicated that Japan's export core manufacturing sectors, such as machinery and electronics, demonstrate strong responses to global demand fluctuations, which further corroborates our findings. The substantial coefficient from the VECM highlights the potential of exports to stimulate economic activity, underscoring the need for policies that bolster export capabilities in response to changing market dynamics.

The results from the Granger causality tests support a robust and statistically significant causal relationship from total exports to GDP across various lag lengths. This consistent pattern implies that changes in export levels can indeed predict fluctuations in GDP, thereby supporting the notion of export-led growth. This aligns with the traditional view in economic literature, particularly the research by Trefler (2004), who argue that exports drive economic growth through avenues such as increased production, enhanced trade revenues, and the R&D channel. In Japan's context, this relationship is particularly salient, given the country's historical focus on innovation and efficiency in its export sectors, which has driven economic resilience even amid global competition (Hogen *et al.*, 2024).

However, the VECM results also reveal limited short-term adjustments in the exports equation, with the first error correction term not being statistically significant. This suggests that, while GDP and exports may be related in the long term, immediate changes in exports do not necessarily lead to corresponding changes in GDP. This finding is reflective of the complex realities of Japan's economy, where structural challenges such as declining domestic demand and an aging population have necessitated a shift in focus towards foreign markets to sustain growth (Nishiguchi (2021), as cited in Hogen *et al.*, (2024)). The interplay of domestic and international market dynamics has led to an environment where exports increasingly depend on broader economic trends rather than direct short-term causality.

Moreover, the variance decomposition analysis indicates that initial shocks to GDP are predominantly explained by its past values, highlighting a high degree of persistence. Over time, while GDP retains a significant influence on its own variance, external factors like imports begin to exert a more considerable impact. This echoes findings by Fabinger *et al.*, (2017) that stress the importance of cheaper intermediate goods from abroad in enhancing competitiveness, which in turn can influence overall economic performance.

The findings from this study align with existing literature, reinforcing the view that exports are crucial drivers of GDP growth in Japan. While the short-term dynamics suggest limited immediate causality, the long-term relationships established through the VECM highlight the importance of exports in shaping Japan's economic future. As Japan navigates contemporary challenges such as declining competitiveness and rising global competition, understanding the intricate relationships between exports and GDP will be essential for informing effective economic policies that leverage Japan's strengths in high-tech and value-added industries (Podoba *et al.*, 2021). This research ultimately contributes to the ongoing dialogue surrounding export-led growth models and their implications for economic policy and international finance.

5 Conclusion

This study provides a comprehensive analysis of the short-run and long-run relationships between exports and GDP in Japan, aiming to determine the existence of bi-directional causality, or feedback effect, between the two variables. Our results reveal that while a strong long-term relationship between GDP, total exports, total imports, and the real exchange rate exists, there is limited evidence of immediate causality from exports to GDP. Our analysis indicates a long-term equilibrium among GDP, exports, imports, and the real exchange rate, emphasizing that these variables move in tandem over extended periods. The long-term negative relationship observed between GDP and imports suggests that an increased reliance on imports may detract from GDP, potentially reducing domestic production's contribution to economic growth. This finding reflects the nuanced effects of trade balance on economic stability, aligning with the perspective that while imports can lower costs for consumers, excessive dependence on foreign goods may pose challenges for sustainable growth.

Our study also highlights the influential role of exports in determining the real exchange rate, with the positive relationship signaling that Japan's export performance may bolster its economic position on the global stage. This aligns with previous research on Japan's core export sectors, like high-tech manufacturing, where robust global demand continues to shape economic resilience. The Granger causality tests further reinforce this by demonstrating a predictive relationship from exports to GDP, supporting the classical export-led growth hypothesis. In Japan's case, this effect underscores how an export-oriented economy can drive national GDP, especially through sectors that emphasize innovation and value-added products, which are key to Japan's competitive edge in international markets.

While the evidence suggests a long-term causality from GDP to exports, short-run adjustments do not show a direct causal link from exports to GDP, indicating that Japan's export performance is increasingly interwoven with broader economic cycles and market trends rather than immediate domestic economic shifts. This finding is particularly relevant given Japan's demographic and economic challenges, such as an aging population and domestic market stagnation, which have pushed Japan's economic focus toward external markets for sustained growth. The persistence seen in GDP's own variance, as shown in the variance decomposition, suggests that while Japan's exports remain essential to its economic strategy, the country's economic trajectory will likely depend on policies that balance export growth with domestic revitalization efforts.

This study contributes to the literature on export-led growth by highlighting Japan's unique case of growth-driven exports and by offering insights into the nuanced relationship between exports and GDP. The findings support the view that Japan's export success is closely tied to its economic foundation, reinforcing the importance of policies that maintain domestic growth and competitiveness. As Japan faces evolving economic challenges, our study suggests that policy measures focused on fostering innovation, improving productivity, and enhancing competitiveness in high-tech sectors will be essential to sustain Japan's position in global markets.

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A Appendix

Table Appendix A.1: ADF Test Results for Initial Time Series

A. ADF Test for Total Exports							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-0.095	-3.354	0.058	17	-3.985	-3.423	-3.135
Constant	0.784	3.373	0.001				
Trend	0.000	2.949	0.003				
Constant Only	-0.014	-1.117	0.708	15	-3.449	-2.870	-2.571
Constant	0.125	1.161	0.246				
No Constant	0.001	1.638	0.976	15	-2.572	-1.942	-1.616
B. ADF Test for Total Imports							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-0.077	-3.053	0.118	15	-3.985	-3.423	-3.135
Constant	0.615	3.082	0.002				
Trend	0.000	2.821	0.005				
Constant Only	-0.010	-1.160	0.690	15	-3.449	-2.870	-2.571
Constant	0.094	1.231	0.219				
No Constant	0.001	1.638	0.976	15	-2.572	-1.942	-1.616
C. ADF Test for GDP							
Specification	Coeff	Statistic	P-value	Lags	1%	5%	10%
Constant and Trend	-0.007	-1.192	0.912	5	-3.984	-3.423	-3.134
Constant	0.083	1.190	0.235				
Trend	0.000	1.435	0.152				
Constant Only	-0.004	-0.664	0.856	5	-3.449	-2.870	-2.571
Constant	0.043	0.667	0.505				
No Constant	0.000	1.087	0.927	5	-2.572	-1.942	-1.616
D. ADF Test for Exchange Rates							
Constant and Trend	-0.015	-1.558	0.809	1	-3.984	-3.423	-3.134
Constant	1.464	1.379	0.169				
Trend	0.001	1.078	0.282				
Constant Only	-0.014	-1.474	0.546	1	-3.449	-2.870	-2.571
Constant	1.635	1.556	0.121				
No Constant	0.001	0.511	0.827	1	-2.572	-1.942	-1.616

Table Appendix A.2: Deterministic Terms and Lagged Endogenous Parameters of the VECM

A. Equation for GDP

Specification	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
L1.GDP	0.7571	0.052	14.445	0.000	[0.654, 0.860]
L1.R	-8.476e-06	8.05e-05	-0.105	0.916	[-0.000, 0.000]
L1.Exp-Total	0.0071	0.004	1.639	0.101	[-0.001, 0.016]
L1.Imp-Total	0.0098	0.004	2.331	0.020	[0.002, 0.018]
L2.GDP	-0.5440	0.058	-9.353	0.000	[-0.658, -0.430]
L2.R	-8.484e-05	9.08e-05	-0.934	0.350	[-0.000, 9.32e-05]
L2.Exp-Total	-0.0026	0.004	-0.684	0.494	[-0.010, 0.005]
L2.Imp-Total	0.0131	0.005	2.648	0.008	[0.003, 0.023]
L3.GDP	0.2078	0.052	3.967	0.000	[0.105, 0.311]
L3.R	-8.146e-05	8.86e-05	-0.920	0.358	[-0.000, 9.21e-05]
L3.Exp-Total	0.0012	0.003	0.369	0.712	[-0.005, 0.007]
L3.Imp-Total	0.0055	0.004	1.493	0.136	[-0.002, 0.013]

B. Equation for Exchange Rates

Specification	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
L1.GDP	-11.3363	34.408	-0.329	0.742	[-78.775, 56.103]
L1.R	0.2926	0.053	5.536	0.000	[0.189, 0.396]
L1.Exp-Total	3.2093	2.857	1.123	0.261	[-2.390, 8.808]
L1.Imp-Total	-3.7093	2.752	-1.348	0.178	[-9.103, 1.684]
L2.GDP	-27.8197	38.182	-0.729	0.466	[-102.656, 47.016]
L2.R	0.0251	0.060	0.421	0.674	[-0.092, 0.142]
L2.Exp-Total	2.0630	2.497	0.826	0.409	[-2.832, 6.958]
L2.Imp-Total	0.5031	3.236	0.155	0.876	[-5.839, 6.846]
L3.GDP	-8.6174	34.397	-0.251	0.802	[-76.033, 58.799]
L3.R	0.0180	0.058	0.309	0.757	[-0.096, 0.132]
L3.Exp-Total	-1.7937	2.112	-0.849	0.396	[-5.934, 2.347]
L3.Imp-Total	-1.2750	2.409	-0.529	0.597	[-5.997, 3.447]

C. Equation for Total Exports

Specification	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
L1.GDP	1.9390	1.077	1.800	0.072	[-0.172, 4.050]
L1.R	0.0057	0.002	3.463	0.001	[0.002, 0.009]
L1.Exp-Total	-0.4874	0.089	-5.450	0.000	[-0.663, -0.312]
L1.Imp-Total	0.0990	0.086	1.150	0.250	[-0.070, 0.268]
L2.GDP	3.0376	1.195	2.541	0.011	[0.695, 5.380]
L2.R	0.0018	0.002	0.945	0.345	[-0.002, 0.005]
L2.Exp-Total	-0.5643	0.078	-7.218	0.000	[-0.718, -0.411]
L2.Imp-Total	-0.0320	0.101	-0.316	0.752	[-0.231, 0.167]
L3.GDP	0.5940	1.077	0.552	0.581	[-1.517, 2.705]
L3.R	0.0018	0.002	0.983	0.326	[-0.002, 0.005]
L3.Exp-Total	0.0207	0.066	0.313	0.755	[-0.109, 0.150]
L3.Imp-Total	0.0748	0.075	0.991	0.322	[-0.073, 0.223]

D. Equation for Total Imports

Specification	Coeff	Std. Error	z	P>|z|	[0.025, 0.975]
L1.GDP	-1.2408	1.281	-0.968	0.333	[-3.753, 1.271]
L1.R	-0.0029	0.002	-1.870	0.061	[-0.006, 0.000]
L1.Exp-Total	0.0143	0.106	0.135	0.893	[-0.193, 0.221]
L1.Imp-Total	-0.4141	0.102	-4.057	0.000	[-0.614, -0.214]
L2.GDP	1.5394	1.421	1.083	0.279	[-1.246, 4.325]
L2.R	0.0030	0.002	1.397	0.162	[-0.001, 0.007]
L2.Exp-Total	-0.0061	0.093	-0.066	0.948	[-0.189, 0.177]
L2.Imp-Total	-0.3097	0.121	-2.559	0.010	[-0.547, -0.072]
L3.GDP	1.0167	1.280	0.794	0.427	[-1.493, 3.527]
L3.R	0.0021	0.002	1.160	0.246	[-0.001, 0.006]
L3.Exp-Total	0.0951	0.079	1.204	0.229	[-0.059, 0.249]
L3.Imp-Total	0.0711	0.090	0.790	0.430	[-0.105, 0.247]

Table Appendix A.3: Bi-directional Causality Test for Exchange Rates and GDP

A. Granger Causality Test from Exchange Rates to GDP				
Number of Lags	Test	Statistic	p-value	df
1	SSR based F test	$F = 1.0111$	0.3153	(360, 1)
	SSR based χ^2 test	$\chi^2 = 1.0195$	0.3126	1
	Likelihood ratio test	$\chi^2 = 1.0181$	0.3130	1
	Parameter F test	$F = 1.0111$	0.3153	(360, 1)
2	SSR based F test	$F = 2.8021$	0.0620	(357, 2)
	SSR based χ^2 test	$\chi^2 = 5.6827$	0.0583	2
	Likelihood ratio test	$\chi^2 = 5.6386$	0.0596	2
	Parameter F test	$F = 2.8021$	0.0620	(357, 2)
3	SSR based F test	$F = 1.3636$	0.2537	(354, 3)
	SSR based χ^2 test	$\chi^2 = 4.1716$	0.2435	3
	Likelihood ratio test	$\chi^2 = 4.1477$	0.2459	3
	Parameter F test	$F = 1.3636$	0.2537	(354, 3)

B. Granger Causality Test from GDP to Exchange Rates				
Number of Lags	Test	Statistic	p-value	df
1	SSR based F test	$F = 10.5892$	0.0012	(360, 1)
	SSR based χ^2 test	$\chi^2 = 10.6775$	0.0011	1
	Likelihood ratio test	$\chi^2 = 10.5234$	0.0012	1
	Parameter F test	$F = 10.5892$	0.0012	(360, 1)
2	SSR based F test	$F = 6.0563$	0.0026	(357, 2)
	SSR based χ^2 test	$\chi^2 = 12.2822$	0.0022	2
	Likelihood ratio test	$\chi^2 = 12.0784$	0.0024	2
	Parameter F test	$F = 6.0563$	0.0026	(357, 2)
3	SSR based F test	$F = 4.6264$	0.0034	(354, 3)
	SSR based χ^2 test	$\chi^2 = 14.1537$	0.0027	3
	Likelihood ratio test	$\chi^2 = 13.8833$	0.0031	3
	Parameter F test	$F = 4.6264$	0.0034	(354, 3)

Table Appendix A.4: Bi-directional Causality Test for Total Imports and GDP

A. Granger Causality Test from Total Imports to GDP

Number of Lags	Test	Statistic	p-value	df
1	SSR based F test	$F = 0.9694$	0.3255	(360, 1)
	SSR based χ^2 test	$\chi^2 = 0.9775$	0.3228	1
	Likelihood ratio test	$\chi^2 = 0.9762$	0.3231	1
	Parameter F test	$F = 0.9694$	0.3255	(360, 1)
2	SSR based F test	$F = 0.7201$	0.4874	(357, 2)
	SSR based χ^2 test	$\chi^2 = 1.4604$	0.4818	2
	Likelihood ratio test	$\chi^2 = 1.4575$	0.4825	2
	Parameter F test	$F = 0.7201$	0.4874	(357, 2)
3	SSR based F test	$F = 1.9601$	0.1196	(354, 3)
	SSR based χ^2 test	$\chi^2 = 5.9967$	0.1118	3
	Likelihood ratio test	$\chi^2 = 5.9475$	0.1142	3
	Parameter F test	$F = 1.9601$	0.1196	(354, 3)

B. Granger Causality Test from GDP to Total Imports

Number of Lags	Test	Statistic	p-value	df
1	SSR based F test	$F = 1.0020$	0.3175	(360, 1)
	SSR based χ^2 test	$\chi^2 = 1.0104$	0.3148	1
	Likelihood ratio test	$\chi^2 = 1.0090$	0.3151	1
	Parameter F test	$F = 1.0020$	0.3175	(360, 1)
2	SSR based F test	$F = 2.1471$	0.1183	(357, 2)
	SSR based χ^2 test	$\chi^2 = 4.3544$	0.1134	2
	Likelihood ratio test	$\chi^2 = 4.3284$	0.1148	2
	Parameter F test	$F = 2.1471$	0.1183	(357, 2)
3	SSR based F test	$F = 2.4962$	0.0596	(354, 3)
	SSR based χ^2 test	$\chi^2 = 7.6368$	0.0541	3
	Likelihood ratio test	$\chi^2 = 7.5571$	0.0561	3
	Parameter F test	$F = 2.4962$	0.0596	(354, 3)