Cointegration Analysis and Forecasting of the Export Function of Bangladesh Using the Error Correction Model

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Abstract
In this paper, we examined the relationship between the growth of the Gross Domestic Product of the United States, the export value index, and the export of Bangladesh over 37 years between 1980 and 2016. The results of our preliminary tests showed that there was indeed a long-run relationship between these variables. Based on our preliminary analysis, we employed an error-correction model to identify the relationship between the variables. The error-correction term with the expected negative sign was statistically significant, and it confirmed that in the case of disequilibrium, the convergence towards the equilibrium happened in the subsequent periods. Additionally, the econometric estimates exhibited that the two-period lagged values of the growth in export of Bangladesh and the growth of the Gross Domestic Product of the United States were also statistically significant.

Keywords: Export function, International trade, Cointegration, Error Correction Model.

JEL Classification: C22, C5, F41.

1. Introduction
Export is one of the major indicators of international trade for a country. As suggested by Altintas and Türker (2014), different countries have been focusing on regional trade integrations since the 1950s. Understandably, for trade balance as well as the accumulation of foreign exchange, export plays a crucial role. For a developing country like Bangladesh, the aggregate value of export is arguably even more significant. Ahmed et al. (1993) investigated the aggregate export–demand function of Bangladesh and found price and income to be inelastic. Numerous other studies have also focused on the export functions of different countries to identify the potential roles of other macroeconomic variables. As suggested by Balassa et al. (1989), the responsiveness of exports to different variables has been deemed to be fundamental in evaluating how effective were the policy measures.

In this paper, we aim to develop a small macro-econometric model for the aggregate export-growth function of Bangladesh. The following sections of this study are as follows: Section 2 of this study reviews the existing econometric pieces of literature to identify and observe the contribution of different macroeconomic variables on export. Section 3 specifies the econometric model of this study, and Section 4 describes the source and outline of the data. The following section 5 focuses on the empirical analysis and the evaluation of the results. Section 6 of this paper provides us the diagnostic assessments of the econometric model employed. Section 7 illustrates the impact of different components and forecasts the growth of the export of Bangladesh over the following periods, whereas section 8 provides the concluding remarks based on the findings.

2. Review of Existing Empirical Works of Literature
As discussed above, export is considered one of the major determinants for the economic growth of a country, especially for developing countries. Over the past few decades, several studies have been conducted to estimate the export function of different countries around the world.1 In this section, we review some of the empirical literature on the export demand function.

Using cointegration analysis and multivariate Granger causation analysis, Altintas and Türker (2014) estimated the import and export functions of Turkey. In their export model, they found the existence of a one-way short-term Granger-causal link from foreign income, real exchange rate and export price

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1 See, for example, Murad, S. M. Woahid (2012), Balassa, B., Voloudakis, E., Fylaktos, P., & Suh, S. T. (1989), Haider, J., Afzal, M. & Riaz, F. (2011), Kabir, R (1988), Dutta, D. and Ahmed, N. (2004) and Islam, T. (2016).
towards export and foreign income, foreign direct investment, real exchange rates, and the export price are the Granger causes of export in the long run. In contrast, in the import model, they showed that there exists a Granger-causality link from Turkey’s real GDP, foreign direct investment, and real exchange rate towards import in the long run. Additionally, single way causality links have been observed from foreign direct investment, real exchange rate, and import price to import.

Sandu and Ghiba (2011) analyzed the effect of the exchange rate on export volumes of Romania. By employing Vector Autoregressive Model (VAR), they found that exports of Romania have a negative relationship with the first lag of the exchange rate, and it is statistically significant, and in their study, they used quarterly data between 2003Q2-2011Q1. Using the annual data from 1970 to 2006, Khattak and Hussain (2010) estimated the determinants of exports of Pakistan. In their study, they used the Johansen cointegration test to find the long-term relationship among total exports, primary commodities exports, semi-manufacturers, and exports of manufactured goods. Furthermore, using Ordinary Least Squares (OLS), they found that an increase in primary commodities exports, semi-manufacturers, and exports of manufactured goods caused an increase in total export volume in Pakistan.

On the other hand, Cheung and Sengupta (2013) conducted a study to examine the effects of the Real Effective Exchange Rate (REER) on specific types of exports instead of total exports. Using data from 2000 to 2010, they determined the effects of the REER on the share of exports of Indian non-financial sector firms. They revealed that firms with small export shares are more affected by the real effective exchange rate fluctuations. In contrast, Sarker (2018) attempted to estimate the import and export demand functions of Bangladesh on a bilateral basis. In his study, he used the Johansen cointegration test approach and vector error correction mechanism, and he found that income is an important determinant of both import and export demand of Bangladesh, whereas price was a less important factor for both export and import demand of Bangladesh.

3. Model Specification of the Growth of Export in Bangladesh

In this section, we focus on developing the econometric specification to model the growth of the export of Bangladesh. Based on the existing empirical literature we reviewed, we understood that several macroeconomic indicators (e.g., foreign GDP, export value index, trade openness, etc.) might have a crucial role to play on the export function of Bangladesh.

According to Houthakker and Magee (1969), trading partner’s income is another dominant factor to influence the volume of export to the trading partner. Since the 1980s, the United States (US) has been the predominant export partner of Bangladesh.\(^2\) So, we have considered the US GDP as one of the major determinants of exports in our model. In contrast, the conventional demand theory says that the consumer is postulated to maximize utility subject to a budget constraint. In this respect, the export demand function is also contingent on the price of exports. In our study, we use the export value index as a proxy of export price.

Therefore, in our estimation, we focus on integrating the growth of US GDP with the export function of Bangladesh. Furthermore, the value of export in proportion to the base period in US Dollar (i.e., the export value index) could be an important variable too in understanding the relationship between the export function of Bangladesh and the growth of US GDP. Therefore, in our study, the export-growth function of Bangladesh is specified as a function of the US GDP and export value index.

Considering the aforementioned factors, the model that we will be focusing on is the following:

\[
l_{\text{export}}_t = \alpha_0 + \alpha_1 * l_{\text{usgdp}}t + \alpha_2 * l_{\text{xvi}}t + \mu_t \tag{1}
\]

Where, for the period \(t\),

\(l_{\text{export}}\) = log of export

\(l_{\text{usgdp}}\) = log of US GDP

\(l_{\text{xvi}}\) = log of export value index and

\(\mu\) = error term.

\(^2\)See: https://wits.worldbank.org/CountryProfile/en/Country/BDG/StartYear/1989/EndYear/2015/TradeFlow/Export/Partner/BY-COUNTRY/Indicator/XPRTPRTNR-SHR#
4. Data and Software

For estimating the export function of Bangladesh, we obtain the annual data of the export of Bangladesh expressed in constant LCU from the International Monetary Fund’s (IMF) various issues of International Financial Statistics (IFS). We also collect data on the export value index of Bangladesh and gross domestic product (GDP) of the US from 1980 to 2016 from the World Bank’s data bank. As a statistical package, we use Gretl to perform all statistical and graphical operations. The details of the tests are available as appendices.

4.1. Summary Statistics of Data

The summary of the data related to $l_{\text{export}}, l_{\text{usgdp}}$ and $l_{\text{xvi}}$ is shown in the table-1. The table shows their means, standard deviation (SD), Coefficient of Variation (CV), skewness, and excess Kurtosis.

| Particulars          | Variable | $l_{\text{export}}$ | $l_{\text{usgdp}}$ | $l_{\text{xvi}}$ |
|----------------------|----------|----------------------|---------------------|------------------|
| Mean                 |          | 12.39                | 15.956              | 4.3316           |
| Median               |          | 12.537               | 16.02               | 4.3964           |
| Minimum              |          | 9.2769               | 14.865              | 2.6711           |
| Maximum              |          | 14.899               | 16.745              | 6.1512           |
| Standard Deviation   |          | 1.6668               | 0.55735             | 1.113            |
| Coefficient of Variation |      | 0.13453              | 0.03493             | 0.25694          |
| Skewness             |          | -0.1004              | -0.327              | 0.04769          |
| Excess Kurtosis      |          | -1.1827              | -1.0873             | -1.2773          |

4.2. Time-Series Plot

The time-series plotting of $l_{\text{export}}, l_{\text{usgdp}}$ and $l_{\text{xvi}}$ is displayed in the Figure-1 below:

![Graphical Plotting of $l_{\text{export}}, l_{\text{usgdp}}$, and $l_{\text{xvi}}$](image)

The initial eye-balling of the graph indicates a probable non-stationarity suggesting the variables may contain a trend.

5. Empirical Analysis

5.1. Stationarity Checking

Although eye-balling indicated a probable non-stationarity among the variables, to formally check for the stationarity, in this section, we analyze the data by plotting the correlograms on levels and by performing Augmented Dickey-Fuller tests both on levels and first differences of $l_{\text{export}}, l_{\text{usgdp}},$ and $l_{\text{xvi}}$. 
5.1.1. Correlogram

The Figure 2 below shows the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) of the three variables:

![Figure 2: Correlograms of l_export, l_usgdp and l_xvi](image)

From Figure 2, for all three of the variables, it becomes clear that the ACFs do not die down and significant at 5% levels for all of them. Therefore, the inspections of the correlograms also point to a non-stationarity.

5.1.2. Unit-root test

At this stage, we employ the Augmented Dickey-Fuller (ADF) to check for the non-stationarity of variables. The Table 2 below shows the ADF tests both on levels and first differences of l_export, l_usgdp, and l_xvi and the conclusions:

| Table 2: Augmented Dickey-Fuller (ADF) test for l_export, l_usgdp and l_xvi |
|--------------------------|------------------|------------------|------------------|------------------|
| Variable                | Parameter        | ADF Statistics   | Asymptotic P-Value | Decision |
| l_export                | Level            | -1.05673         | 0.9345            | I(1)      |
|                         | First diff.      | -7.22703         | 5.422e-007        | I(1)      |
| l_usgdp                 | Level            | -2.03729         | 0.5802            | I(1)      |
|                         | First diff.      | -4.17009         | 0.002471          | I(1)      |
| l_xvi                   | Level            | -2.99321         | 0.134             | I(1)      |
|                         | First diff.      | -8.69248         | 2.321e-008        |           |

\( H_0: \text{the variable has a unit root} \)

\( \text{Testing down from 4 lags, criterion AIC} \)

The ADF tests confirm that all three variables are non-stationary at levels but stationary at first differences. Therefore, the test confirms that all the variables are integrated at the order one [I(1)].

5.2. Collinearity Checking

To inspect for the probable collinearity between the first differences of the variables, we perform a collinearity checking. The results of the Belsley-Kuh-Welsch test are stated below in the Table 3:

| Table 3: Belsley-Kuh-Welsch Collinearity Diagnostics |
|----------------|----------------|----------------|----------------|----------------|
| lambda         | cond           | Const          | d_l_export     | d_l_usgdp      | d_l_xvi        |
| 3.450          | 1.000          | 0.011          | 0.010          | 0.009          | 0.026          |
| 0.367          | 3.064          | 0.028          | 0.013          | 0.032          | 0.938          |
| 0.108          | 5.663          | 0.696          | 0.573          | 0.006          | 0.008          |
| 0.075          | 6.777          | 0.265          | 0.403          | 0.953          | 0.027          |

As the conditions (cond) are less than 10, the results show that there is no evidence of excessive collinearity between them.
5.3. Vector Autoregression (VAR) Lag-Length Selection

Before performing a VAR model (and a probable VAR with error correction), we perform the operations to calculate different information criteria to identify the suitable lag(s) for our models. Table-4 below summarizes the data of the calculation:

| lags | AIC     | BIC     | HQC     |
|------|---------|---------|---------|
| 1    | -11.018092 | -10.473907* | -10.834990 |
| 2    | -11.376456 | -10.424133  | -11.056028 |
| 3    | 11.327490  | -9.967029   | -10.869736 |
| 4    | -11.836434* | -10.067834  | -11.241354* |

Based on the Akaike Information Criterion (AIC), the lag-length (p) of a VAR analysis should be 4 (indicated by the asterisk) as it minimizes the AIC value. Therefore, for the Johansen cointegration test, the lag-length of (p-1) or 3 seems like a rational selection.

5.4. Cointegration Tests

Before the selection of the model, we need to check the variables for cointegration, i.e., if there exists a stationary long-run relationship concerning their movements from each other. To check for cointegration, in this section, we employ the Engle-Granger test and the Johansen test.

5.4.1. Engle-Granger Test

Based on Engle and Granger (1987), in this section, we check for the stationarity of the residuals. The summary of the Engle-Granger test is stated below:

| Rank | Trace Test | λ_{max} Test |
|------|------------|--------------|
|      | Test stat  | p-value      | Test stat | p-value     |
| 0    | 34.157     | 0.0307       | 18.181    | 0.1263      |
| 1    | 15.976     | 0.0549       | 9.3699    | 0.2624      |
| 2    | 6.6059     | 0.0152       | 6.6059    | 0.0102      |

Here, the p-value < 0.05, therefore the Engle-Granger test rejects the null hypothesis at a 5% significance level. This means, there is at least 1(one) cointegrating relationship between the variables.

5.4.2. Johansen Cointegration Test

Based on Johansen (1988), in this section, we conduct the cointegration test. As stated above, for the Johansen cointegration test, the lag-length of three would be our selection. Now, corrected for sample size, the details of the trace test and eigenvalue test are shown below:

As per the standard practice, the trace test outcomes take precedence over the λ_{max} (eigenvalue) test. So, at 5% significance level, we reject the H_{0}: Rank 0, which means that there exists one long-run relationship between the variables. The long-run relationship under there parameters is denoted by the following equation (derived from the renormalized vector):

\[ l_{\text{export}} = 0.94687 \times l_{\text{usgdp}} + 0.91169 \times l_{xvi} \]
5.5. Vector Error Correction Model (VECM)

As the variables $l_{\text{export}}, l_{\text{usgdp}}$ and $l_{\text{xvi}}$ show the presence of a cointegration relationship between them, we need to formulate our model incorporating an error-correction term into it. Theoretically, the model now becomes,

$$\Delta l_{\text{exp}} = a_0 + \sum_1^n a_1 \Delta l_{\text{exp}}_{t-i} + \sum_1^n a_2 \Delta l_{\text{usgdp}}_{t-i} + \sum_1^n a_3 \Delta l_{\text{xvi}}_{t-i} + \alpha_4 EC_{t-1} + \mu_t$$

(2)

Where, $EC_{t-1}$ = the error correction term lagged one period.

The results of the VECM is shown below:

| Variables   | Coefficient | Std. Error | t-ratio | p-value | Significance |
|-------------|-------------|------------|---------|---------|--------------|
| $a_0$       | -1.90493    | 0.616359   | -3.091  | 0.0047  | ***          |
| $\Delta l_{\text{exp}}_{t-1}$ | 0.684124    | 0.211369   | 3.237   | 0.0033  | ***          |
| $\Delta l_{\text{exp}}_{t-2}$ | -0.0330907  | 0.133698   | -0.2475 | 0.8065  |              |
| $\Delta l_{\text{usgdp}}_{t-1}$ | -0.701877   | 0.500416   | -1.403  | 0.1726  |              |
| $\Delta l_{\text{usgdp}}_{t-2}$ | -1.25386    | 0.569316   | -2.202  | 0.0367  | ***          |
| $\Delta l_{\text{xvi}}_{t-1}$   | -0.208487   | 0.101467   | -2.055  | 0.0501  | *            |
| $EC_{t-1}$ | -0.312381   | 0.0961600  | -3.249  | 0.0032  | ***          |

Note: *, ** and *** denotes significance at 10%, 5% and 1% significance level respectively

The statistical measures of this model are stated below:

| Table-7: Statistical Measures of the Model |
|------------------------------------------|
| Mean of Dependent Variable | 0.145301 | SD of Dependent Variable | 0.052875 |
| Sum of Squared Residuals     | 0.044214 | SE of Regression         | 0.041237 |
| R-squared Value              | 0.520766 | Adjusted R-squared value | 0.391742 |
| Rho                        | -0.006499 | Durbin-Watson Value      | 2.005787 |

The results from the model (in Table-6) show that the error-correction term $EC_{t-1}$ is statistically highly significant (even at a 1% significance level), and expectedly it has a negative sign. This points to the soundness of our equation (1), indicating that between the variable, there is indeed a long-term equilibrium relationship. The coefficient of $EC_{t-1}$ (-0.312381) shows that in case of a deviation, the variables converge to the equilibrium by adjusting the preceding period’s disequilibrium at over 31% in the following period.

Furthermore, the intercept, $\Delta l_{\text{exp}}_{t-1}$ and $\Delta l_{\text{usgdp}}_{t-2}$ are significant at a 5% significance level. In contrast, $\Delta l_{\text{xvi}}_{t-1}$ is significant at a 10% significant level. Concerning the coefficients, the elasticity of the two-period lagged value of the change in the growth of the US GDP is more than unit-elastic (-1.25386). However, although it is less than unity (0.684124), the sign is positive for the one-period lagged value of the change in the growth of the export (as we would expect from the economic standpoint) indicating that the current period’s value increases at a lesser rate.

From Table-7, we see that the R-squared and the adjusted R-squared values are 0.520766 and 0.391742, respectively. Furthermore, the Rho of -0.006499 and the Durbin-Watson (DW) value of around 2 indicates the presence of an insignificant autocorrelation in the model.
6. Diagnostic Tests

Although the initial diagnostics (stated above) show no apparent misspecification with very little sign of autocorrelation in our model (with the DW stat of 2.005787), we perform additional diagnostic tests to check for probable conditional heteroskedasticity and non-normality.

6.1. Autoregressive Conditional Heteroskedasticity (ARCH) Test:

To check for the probable conditional heteroskedasticity in our model, we conduct the test for the presence of ARCH. The results of the ARCH test is stated in the table below:

| Lag | LM       | df | p-value |
|-----|----------|----|---------|
| 1   | 47.057   | 36 | 0.1027  |
| 2   | 81.559   | 72 | 0.2064  |
| 3   | 119.110  | 108| 0.2187  |

The test results from the Table-8 show that the ARCH test fails to reject the null hypothesis ($H_0$: No conditional heteroskedasticity) at a 5 % significance level. Thus, the test confirms that there is no problem with conditional heteroskedasticity in our model.

6.2. Normality Test

The test to check for the normality in the model is crucial, as it would ensure the forecasting-ability of our model. To check for a probable non-normality, we perform the Doornik-Hansen test. The results of the test are stated below:

| Test Stat                       | p-value |
|---------------------------------|---------|
| Chi-square(6) = 7.67642         | 0.2628  |

The test result from the Table-9 states that the Doornik-Hansen test fails to reject the null hypothesis at a 5 % significance level. Therefore, the test confirms that the residuals are normally distributed.

7. Forecasting

In this section, we focus on the variance decomposition of the forecast, the impulse responses to innovations, and the forecasting of $l_{export}$ over the periods following our study.

7.1. Decomposition of Variance

As we know, the variance decomposition of forecasting measures how each type of shock impacts the error variance of the forecast. The Table-10 below shows the variance decomposition of $l_{export}$:

| Period | Standard Error | $l_{export}$ | $l_{usgdp}$ | $l_{xvi}$ |
|--------|----------------|--------------|-------------|-----------|
| 1      | 0.036061       | 100.0000     | 0.0000      | 0.0000    |
| 2      | 0.0625141      | 98.8653      | 0.6535      | 0.4812    |
| 3      | 0.0863231      | 87.4304      | 6.8454      | 5.7242    |
| 4      | 0.109012       | 75.4082      | 13.0470     | 11.5449   |
| 5      | 0.126999       | 68.0547      | 15.2993     | 16.6459   |
| 6      | 0.139833       | 64.1491      | 15.0935     | 20.7574   |
| 7      | 0.14957        | 61.9289      | 13.9987     | 24.0724   |
| 8      | 0.157964       | 60.5371      | 12.7519     | 26.7110   |
| 9      | 0.166016       | 59.4897      | 11.5903     | 28.9200   |
| 10     | 0.174118       | 58.5210      | 10.5523     | 30.9267   |
The following Figure-3 graphically represents the variance decomposition of the forecast for $l_{\text{export}}$:

![Figure-3: Forecast of Variance Decomposition for $l_{\text{export}}$](image)

As illustrated by Table-10 and Figure-3, although initially higher, the innovation in the growth of the US GDP has a lesser effect comparing to the growth of the export value index in the long run.

### 7.2. Impulse Response Functions

To check for the impact of a one standard deviation shock to the model, we check for the impulse response functions. The responses are graphically shown in the figure below:

![Figure-4: Impulse Response Functions of $l_{\text{export}}$ (with 95% Confidence Band)](image)

As it is evident from the Figure-4, the impacts on $l_{\text{export}}$ to a shock to $l_{\text{usgdgdp}}$ and $l_{\text{export}}$ are of a short-run nature. In contrast, a shock to $l_{xvi}$ has a longer-term impact on $l_{\text{export}}$. In contrast, the response of $l_{\text{export}}$ to a shock to $l_{\text{usgdgdp}}$ is negative, unlike the other two.

### 7.3. Forecasting of the Growth in Export

As our model passed our diagnostic tests, in this section, we forecast the growth in export for the subsequent five periods (2017-2021). The representation below in the Figure-4 includes the fitted values for the pre-forecast range to illustrate the fit of our model graphically.

![Figure-4: Forecast of $l_{\text{export}}$ (Including Fitted Values for Pre-forecast Range)](image)

As illustrated by Figure-4, our model forecasts a steady increase in the growth of export over the forecasting period of five years subsequent to our analysis period between 1980 and 2016.
8. Conclusion

In this study, we examined the impact of the growth of US GDP and the export value index on the growth of the export of Bangladesh. We focused on the period between 1980 and 2016 in our analysis. As a standard method of dealing with time-series data, we initially focused on identifying a probable non-stationarity of the variables. Apart from the inspection of correlograms, the subsequent ADF tests confirmed the presence of a non-stationarity among all three variables in question. Therefore, before selecting our desired model, we conducted the Engle-Granger test and the Johansen test to observe whether there exists a cointegration between the variables. The empirical analysis showed that there is a long-run relationship between the variables, as evident by the results.

In the presence of a long-run relationship between the variables, we modeled the variables using an error-correction model. After defining the parameters and running the model, we conducted the diagnostic checks that indicated no significant presence of a serial correlation, conditional heteroskedasticity, or non-normality in our model. Following our diagnostic tests, we inspected the impulse response functions and found out that the impacts on the growth of export to a shock to the growth of the US GDP were of a short-run nature, whereas the impact to a shock to the growth of the export value index was a longer-run one. Furthermore, our error-correction rate of over 31% showed that in the case of disequilibrium in the preceding period, the adjustment to the equilibrium would happen at a significant rate. And, according to our forecast, assuming these existing conditions hold, we would expect the growth rate of the export of Bangladesh to increase at a steady rate over the periods following our study.
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Appendices

Appendix-A

Collinearity Checking
Belsley-Kuh-Welsch collinearity diagnostics:

| lambda | cond | const | d_l_export | d_l_usgdp | d_l_xvi |
|--------|------|-------|------------|-----------|--------|
| 3.450  | 1.000| 0.011 | 0.010      | 0.009     | 0.026  |
| 0.367  | 3.064| 0.028 | 0.013      | 0.032     | 0.938  |
| 0.108  | 5.663| 0.696 | 0.573      | 0.006     | 0.008  |
| 0.075  | 6.777| 0.265 | 0.403      | 0.953     | 0.027  |

lambda = eigenvalues of inverse covariance matrix (smallest is 0.0751256)
cond   = condition index
note: variance proportions columns sum to 1.0
According to BKW, cond $\geq 30$ indicates “strong” near-linear dependence, and cond between 10 and 30 “moderately strong”. Parameter estimates whose variance is mostly associated with problematic cond values may themselves be considered problematic.
Count of condition indices $\geq 30$: 0
Count of condition indices $\geq 10$: 0

Result: No evidence of excessive collinearity

Appendix-B

VAR Lag-Length Selection
VAR system, maximum lag order 4:
The asterisks below indicate the best (that is, minimized) values of the respective information criteria.
AIC = Akaike criterion,
BIC = Schwarz Bayesian criterion and
HQC = Hannan-Quinn criterion.

| lags | loglik | p(LR) | AIC       | BIC       | HQC       |
|------|--------|-------|-----------|-----------|-----------|
| 1    | 193.79852| -     | -11.018092| -10.473907*| -10.834990|
| 2    | 208.71153| 0.00047| -11.376456| -10.424133| -11.056028|
| 3    | 216.90359| 0.05928| 11.327490 | -9.967029 | -10.869736|
| 4    | 234.30116| 0.00006| -11.836434*| -10.067834| -11.241354*|
Appendix-C

Engle-Granger Test for Integration

Step 1: cointegrating regression

Cointegrating regression -
OLS, using observations 1980-2016 (T = 37)
Dependent variable: l_export

| coefficient | std. error | t-ratio  | p-value |
|-------------|------------|----------|---------|
| const       | -13.2355   | 1.95650  | -6.765  | 8.90e-08 *** |
| l_usgdp     | 1.38686    | 0.141488 | 9.802   | 1.94e-011 *** |
| l_xvi       | 0.807377   | 0.0708539| 11.39   | 3.72e-013 *** |

Mean dependent var 12.39008
S.D. dependent var 1.666790
Sum squared resid 0.247564
S.E. of regression 0.085330
R-squared 0.997525
Adjusted R-squared 0.997379
Log-likelihood 40.12885
Akaike criterion -74.25771
Schwarz criterion -69.42496
Hannan-Quinn -72.55394
rho 0.326753
Durbin-Watson 1.068633

Step 2: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
testing down from 4 lags, criterion AIC
sample size 36
unit-root null hypothesis: a = 1
test without constant
including 0 lags of (1-L)uhat
model: (1-L)y = (a-1)*y(-1) + e
estimated value of (a - 1): -0.673247
test statistic: tau_c(3) = -5.02535
p-value 0.004799
1st-order autocorrelation coeff. for e: 0.146

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables, and
(b) the unit-root hypothesis is rejected for the residuals (uhat) from the
cointegrating regression.
Appendix-D

Johansen Cointegration Test
Number of equations = 3
Lag order = 3
Estimation period: 1983 - 2016 (T = 34)
Case 3: Unrestricted constant

Log-likelihood = 318.372 (including constant term: 221.884)

| Rank | Eigenvalue | Trace test p-value | Lmax test p-value |
|------|------------|--------------------|-------------------|
| 0    | 0.41418    | 34.157 [0.0139]    | 18.181 [0.1263]   |
| 1    | 0.24087    | 15.976 [0.0407]    | 9.3699 [0.2624]   |
| 2    | 0.17658    | 6.6059 [0.0102]    | 6.6059 [0.0102]   |

Corrected for sample size (df = 24)

| Rank | Trace test p-value |
|------|--------------------|
| 0    | 34.157 [0.0307]    |
| 1    | 15.976 [0.0549]    |
| 2    | 6.6059 [0.0152]    |

eigenvalue     0.41418      0.24087      0.17658

beta (cointegrating vectors)
\[
\begin{align*}
\text{l\_export} & \quad -13.597 & 1.5495 & -20.569 \\
\text{l\_usgdp} & \quad 12.875 & -17.014 & 17.941 \\
\text{l\_xvi} & \quad 12.396 & 5.6541 & 22.230 \\
\end{align*}
\]

alpha (adjustment vectors)
\[
\begin{align*}
\text{l\_export} & \quad 0.022974 & -0.010382 & -0.0043334 \\
\text{l\_usgdp} & \quad 0.0066546 & 0.0030564 & -0.0039392 \\
\text{l\_xvi} & \quad 9.9322e-005 & -0.021941 & -0.023001 \\
\end{align*}
\]

renormalized beta
\[
\begin{align*}
\text{l\_export} & \quad 1.0000 & -0.091067 & -0.92529 \\
\text{l\_usgdp} & \quad -0.94687 & 1.0000 & 0.80703 \\
\text{l\_xvi} & \quad -0.91169 & -0.33232 & 1.0000 \\
\end{align*}
\]

renormalized alpha
\[
\begin{align*}
\text{l\_export} & \quad -0.31238 & 0.17665 & -0.096334 \\
\text{l\_usgdp} & \quad -0.090482 & -0.052002 & -0.087570 \\
\text{l\_xvi} & \quad -0.0013505 & 0.37331 & -0.51133 \\
\end{align*}
\]

long-run matrix (alpha * beta')
\[
\begin{align*}
\text{l\_export} & \quad -0.23933 & 0.39469 & 0.12976 \\
\text{l\_usgdp} & \quad -0.0047197 & -0.036998 & 0.012203 \\
\text{l\_xvi} & \quad 0.43778 & -0.038071 & -0.63416 \\
\end{align*}
\]
Appendix-E

VECM Estimation

VECM system, lag order 3
Maximum likelihood estimates, observations 1983-2016 (T = 34)
Cointegration rank = 1
Case 3: Unrestricted constant
beta (cointegrating vectors, standard errors in parentheses)

\[ \begin{align*}
&\text{l\_export} & 1.0000 & (0.00000) \\
&\text{l\_usgdp} & -0.94687 & (0.26794) \\
&\text{l\_xvi} & -0.91169 & (0.12839) \\
\end{align*} \]

alpha (adjustment vectors)

\[ \begin{align*}
&\text{l\_export} & -0.31238 \\
&\text{l\_usgdp} & -0.090482 \\
&\text{l\_xvi} & -0.0013505 \\
\end{align*} \]

Log-likelihood = 213.8966
Determinant of covariance matrix = 6.8899718e-010
AIC = -10.8174
BIC = -9.4707
HQC = -10.3582

Equation 1: \( d\_l\_export \)

| Coefficient | Std. Error | t-ratio | p-value |
|-------------|------------|---------|---------|
| const       | -1.90493   | 0.616359| -3.091  | 0.0047  *** |
| d\_l\_export\_1 | 0.684124   | 0.211369| 3.237   | 0.0033  *** |
| d\_l\_export\_2 | -0.0330907 | 0.133698| -0.2475 | 0.8065  |
| d\_l\_usgdp\_1 | -0.701877  | 0.500416| -1.403  | 0.1726  |
| d\_l\_usgdp\_2 | -1.25386   | 0.569316| -2.202  | 0.0367  ** |
| d\_l\_xvi\_1  | -0.208487  | 0.101467| -2.055  | 0.0501  * |
| d\_l\_xvi\_2  | 0.0120836  | 0.0961600| 3.249   | 0.0032  *** |
| EC1          | -0.31238   | 0.0961600| -3.249  | 0.0032  *** |

Mean dependent var | 0.145301 | SD dependent var | 0.052875
Sum squared resid  | 0.04214  | SE of regression  | 0.041237
R-squared          | 0.520766 | Adjusted R-squared | 0.391742
rho                | -0.006499 | Durbin-Watson  | 2.005787

Equation 2: \( d\_l\_usgdp \)

| Coefficient | Std. Error | t-ratio | p-value |
|-------------|------------|---------|---------|
| const       | -0.559423  | 0.235158| -2.379  | 0.0250  ** |
| d\_l\_export\_1 | 0.00337318 | 0.0806435| 0.04183 | 0.9670  |
| d\_l\_export\_2 | 0.106251  | 0.0510097| 2.083   | 0.0472  ** |
| d\_l\_usgdp\_1 | 0.612569   | 0.190923| 3.208   | 0.0035  *** |
| d\_l\_usgdp\_2 | -0.542343  | 0.217210| -2.497  | 0.0192  ** |
| d\_l\_xvi\_1  | -0.101971  | 0.0387126| -2.634  | 0.0140  ** |
| d\_l\_xvi\_2  | -0.0142083 | 0.0351196| -0.4046 | 0.6891  |
| EC1          | -0.0904822 | 0.0366878| -2.466  | 0.0206  ** |
Equation 3: $d_{l_xvi}$

| Coefficient | Std. Error | $t$-ratio | p-value |
|-------------|------------|-----------|---------|
| const       | 0.148535   | 1.20797   | 0.1230  | 0.9031  |
| $d_{l_{export}_1}$ | 0.806810 | 0.414251  | 1.948   | 0.0623  |
| $d_{l_{export}_2}$ | -0.164848 | 0.262028  | -0.6291 | 0.5348  |
| $d_{l_{usgdp}_1}$ | 0.343830  | 0.980736  | 0.3506  | 0.7287  |
| $d_{l_{usgdp}_2}$ | -1.83494  | 1.11577   | -1.645  | 0.1121  |
| $d_{l_{xvi}_1}$ | -0.710820 | 0.198860  | -3.574  | 0.0014  |
| $d_{l_{xvi}_2}$ | -0.0262760 | 0.180403  | -0.1457 | 0.8853  |
| $EC1$       | -0.00135048 | 0.188459  | -0.007166 | 0.9943  |

Mean dependent var | 0.098516 | SD dependent var | 0.097714
Sum squared resid | 0.169824 | SE of regression | 0.080819
R-squared | 0.461024 | Adjusted R-squared | 0.315915
rho | 0.154804 | Durbin-Watson | 1.690158

Cross-equation covariance matrix:

| l_export | l_{usgdp1_xvi} |
|----------|---------------|
| l_export | 0.0013004     | 0.00018117  | 0.0015134 |
| l_{usgdp} | 0.00018117   | 0.00018929  | 0.00023565 |
| l_{xvi}  | 0.0015134    | 0.00023565  | 0.0049948  |

Determinant = 6.88997e-010
Appendix-E

Normality Test
Residual correlation matrix, C (3 x 3):

\[
\begin{pmatrix}
1.0000 & 0.36516 & 0.59383 \\
0.36516 & 1.0000 & 0.24235 \\
0.59383 & 0.24235 & 1.0000
\end{pmatrix}
\]

Eigenvalues of C:

0.389669
0.790058
1.82027

The Doornik-Hansen test: Test for null hypothesis of normal distribution
Chi-square(6) = 7.67642 [0.2628]

Appendix-F

Forecasting for 5 Periods:
For 95% confidence intervals, z(0.025) = 1.96

| Obs | i_export | prediction | std. error | 95% interval          |
|-----|----------|------------|------------|----------------------|
| 2017| undefined| 15.0082    | 0.0360610  | (14.9376, 15.0789)   |
| 2018| undefined| 15.1548    | 0.0625141  | (15.0323, 15.2773)   |
| 2019| undefined| 15.3121    | 0.0863231  | (15.1429, 15.4812)   |
| 2020| undefined| 15.4637    | 0.109012   | (15.2500, 15.6773)   |
| 2021| undefined| 15.6043    | 0.126999   | (15.3554, 15.8532)   |