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Testing the Nexus between Imported Capital Goods and Manufacturing Output in Bangladesh

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Abstract

Considering the increasing importance of imported capital goods in the developing economy's manufacturing sector, our empirical study explores the relationship between imported capital goods, inflation, financial development, trade openness, and manufacturing output in Bangladesh using data from 1991 to 2022. The econometric analyses utilize the augmented ARDL (Auto-regressive Distributed Lag) model, frequency domain causality, and counterfactual analysis. The results suggest a significant connection between the import of capital goods and manufacturing output in Bangladesh in the near and long term. Specifically, a favorable long-term association exists between imported capital goods and manufacturing output. Furthermore, short-term adjustments are consistently made to uphold this association. The frequency domain causality analysis and counterfactual analysis also support the findings of the augmented ARDL approach. In addition, this study also emphasizes that inflation and trade openness adversely impact manufacturing output, while financial development positively influences manufacturing output in the economy.

Keywords: Augmented ARDL, Bangladesh, Imported Capital Goods, Manufacturing Output, Trade Openness
JEL Classification: C32, F14, F41, O14

1. Introduction

Insufficient technological advancement is widely acknowledged as the main obstacle to long-term economic development in developing countries. Technologically backward countries can experience rapid growth like industrialized nations by adopting and implementing foreign innovations in domestic manufacturing (Mohamed et al., 2022). Importing capital goods, which often contain embedded knowledge in machinery and equipment, can be viewed as a systematic way of acquiring foreign technologies. The import of capital goods that incorporate advanced technologies is essential for the development process because it significantly affects manufacturing output (Habiyaremye,

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2013; Usman & Bashar, 2022). Developing countries often lack the resources and specialized skills to generate technological knowledge. Acquiring this expertise domestically can be exceedingly costly for these nations (Sarker & Khan, 2020). Therefore, importing these technologies is a logical choice to acquire the necessary technological capital, given the limitations of the domestic technological gap (Ayeni & Akeju, 2023; Mustafin et al., 2022).

Due to inadequate technological advancement, capital goods imports can significantly contribute to manufacturing performance in developing countries like Bangladesh (Chowdhury et al., 2023; Rahman et al., 2023). The manufacturing sector in the country started to grow in the 1990s following the introduction of trade and financial liberalization policies. As a result, the manufacturing industry heavily depends on imported raw materials and capital goods (Swazan & Das, 2022). Although from the beginning of manufacturing expansion, the economy has benefited from cheap labor due to its comparative advantage of having an excessive labor supply (Ahmed et al., 2014). However, the country's heavy reliance on low-cost labor could restrict production growth. On the other hand, imports of capital machinery and technological equipment from abroad are required for higher manufacturing growth through increased labor productivity (Liao et al., 2023). Therefore, imported capital goods are crucial for the country's manufacturing growth because they bring technology and advanced manufacturing processes (Wahab et al., 2016).

Bangladesh's economy has shown a prospective growth rate of around 6 percent annually in recent years. The manufacturing industry has been pivotal in this expansion, especially through the advancement of the ready-made garment (RMG) sectors (Gu et al., 2021). Relying on RMG manufacturing, the country has experienced export-oriented growth, with the RMG industry contributing to more than 80 percent of the total exports (Islam & Halim, 2022). Agriculture dominated the economy in the past, but in recent years, manufacturing has become the driving force behind economic growth by enabling exports. The contribution of manufacturing value added to GDP was around 22 percent in 2022, compared to approximately 14 percent in 1991 (The World Bank, 2024).

In the era of industrialization, economic growth was driven by increased manufacturing performance. Simultaneously, the importation of capital goods also fostered manufacturing contribution by facilitating the transfer of technological capital and technical know-how. Transferring technology by importing capital goods is a prerequisite because the economy has a comparative disadvantage in producing technological capital (Hossain & Alauddin, 2005). Trade openness and financial development have helped boost the country's manufacturing exports, and importing capital goods has facilitated these exports (Sarker, 2024). Although the country used to rely heavily on imports for consumer products and food after gaining independence, it has steadily shifted towards importing capital goods to promote manufacturing growth (Hosen, 2023). In 2022, the volume of imported capital goods to the GDP was more than 6 percent; in 1991, it was only 1.64 percent (Bangladesh Bank, 2024). The swift rise in imports of capital goods, along with the growing proportion of manufacturing value added to GDP, serves as proof of a strong link between the import of capital goods and the manufacturing performance within the economy.

In addition, economic theory suggests that imported capital goods have considerable merit in increasing manufacturing growth in technologically backward countries in light of proper international trade mechanisms (Sankaran, et al., 2021). The increasing imports of capital goods in Bangladesh can also contribute to manufacturing growth as Bangladesh's manufacturing highly relies on imports of technological capital, which could be observed since the period of economic liberalization (Hoque & Yusop, 2010).

Meanwhile, no previous empirical research has been identified regarding the long-term relationship between imported capital goods and the growth of manufacturing. The labor-intensive manufacturing sector in Bangladesh increasingly depends on imported capital goods for technology transfer. Effectively implementing technological advancements is crucial for achieving competitive and sustainable growth in manufacturing. Thus, it is important to understand how imported capital goods affect the manufacturing growth of the country by exploring both the long-term and short-term relationships between capital goods imports and manufacturing performance in Bangladesh.

This study seeks to explore the causal relationship between the importation of capital goods and the growth of manufacturing in Bangladesh, based on the hypothesis that imported capital goods have a positive impact on manufacturing expansion. To understand the connection between imported capital goods and manufacturing growth, we take into account control factors such as inflation rates, financial development, and trade openness. By employing the augmented Auto-regressive Distributed Lag (ARDL) model, this research investigates the cointegrating relationships among capital goods, inflation, financial development, trade openness, and manufacturing output in Bangladesh. Additionally, this study utilizes frequency-domain causality to discern the short-term, medium-term, and long-term causal relationships among the variables. Lastly, we implement the innovative dynamic ARDL simulation method to analyze the effects of hypothetical shocks in independent variables on the dependent variable of this study.

This research is organized in the following manner: Section-2 reviews the current literature to comprehend the connections among the variables. Section-3 provides an overview of the methodology and the data used. Section-4 presents the empirical results along with a discussion of the findings. Lastly, Section-5 wraps up the study with policy implications.

2. Literature Review

2.1 Theoretical Underpinnings

Theories suggest that countries with a comparative disadvantage in capital goods primarily import technological capital from developed nations with a comparative advantage in capital technologies (Thangavelu & Rajaguru, 2004). The endogenous growth hypothesis posits that such imports contribute to long-term growth by providing essential technological capital and intermediate goods for manufacturing (Coe et al., 2009). Additionally, imports of capital goods facilitate the transfer of technology and know-how from developed to developing countries (Lawrence & Weinstein, 1999; Mazumder, 2001; Sharma et al., 2023). The import-led growth hypothesis further indicates that imports drive growth through advanced technology (Krishna et al., 2003; Li et al., 2021). In developing countries, imports are crucial for exports, and both processes promote economic development, highlighting a reciprocal relationship (Awokuse, 2007, 2008).

The relationship between imported capital goods and manufacturing output can be explained by the import-led economic growth hypothesis, particularly in countries reliant on imports for production (Kim et al., 2022). Importing capital goods promotes technological advancement and enhances competitiveness and economic prospects (Liao et al., 2023; Panta et al., 2022). Thus, trade openness and foreign capital inputs are vital for output growth, while reducing such imports in developing countries may negatively impact their economies (Nguyen et al., 2023; Singh, 2010). Our research examines how imported capital goods influence manufacturing output in Bangladesh.

2.2 Empirical Evidence from the Global Perspective

Many scholars have examined the relationship between imports and economic growth, particularly focusing on imported capital goods and manufacturing output. Aluko and Obalade (2020) studied 26 African countries and found no causal link between imports and growth in over half of them. Conversely, Aluko and Adeyeye (2020) reported a two-way causal linkage in most of the 41 sampled African countries. Hye et al. (2013) found that imported capital goods significantly boost economic development in South Asia, while Usman and Bashir (2022) identified a significant association between imports and economic growth in the short and long term in China, India, and G7 countries.

Islam et al. (2012) found that in high-income countries, imports significantly drive economic growth, whereas low-income countries exhibit a bidirectional relationship between imports and growth. Veeramani (2009) highlighted that the import of intermediate and capital goods boosts output and economic development in both income groups. Zang and Baimbridge (2012) noted a positive long-term correlation between imports and economic growth in Japan and Korea, with bidirectional causality. Raghutla and Chittedi (2020) revealed that imports significantly contribute to economic growth in Russia within the BRICS countries.

Herrerias and Orts (2013) examined the impact of imported capital goods on China's economic growth and per capita income, finding that they boost domestic production and economic development. In Jordan, Istaiteyeh et al. (2023) noted a short-run causal link between imports and economic growth, while the long-run correlation is less significant. Maitra (2020) analyzed India's post-1990s economy and found that imports positively affect growth in both the short and long term. Similarly, Ugur (2008) identified a bidirectional causal relationship between imported capital goods and GDP growth in Turkey.

2.3 Empirical Evidence from Bangladesh Context

In Bangladesh, while the export-growth relationship has been widely studied, research on the import-growth relationship, particularly regarding capital goods and manufacturing output, is limited. Ahmed and Uddin (2009) analyzed data from 1976 to 2005 and found a short-run positive association between imports and economic growth, but no significant long-run relationship. Conversely, Dawson (2006) investigated the link between exports, imports, and GDP from 1973 to 2003, identifying a negative correlation between imports and GDP.

Hossain et al. (2009) found that while imports do not significantly affect economic growth, exports are highly positively correlated with it. They noted that exports are positively associated with imports both in the short and long run. Paul (2011) analyzed data from 1979 to 2010, confirming that exports positively influence long-term economic growth, with imports having no substantial impact. Most studies in the Bangladesh context examined a mix of pre- and post-reform eras. In contrast, Wahab et al. (2016) focused on the liberalized period from 1985 to 2014, finding that imports of capital goods significantly contribute to long-term manufacturing growth, but showed no short-run correlation with manufacturing output.

2.4 Research Gap

The review of the literature indicates a mixed relationship between imports and economic growth in developing countries. While some studies suggest that imports fuel growth, others do not support this view. Notably, there is a lack of empirical studies examining the impact of imported capital goods on manufacturing output using advanced econometric techniques in a developing country context. In Bangladesh, the relationship remains inconclusive, and there has been no comprehensive study on imported capital goods and manufacturing output. Given that the manufacturing sector heavily relies on imported technological capital, it is crucial to investigate this relationship using recent data and sophisticated methods.

Therefore, this study explores how imported capital goods affect manufacturing growth in technology-constrained, import-dependent developing countries like Bangladesh. It aims to provide insights for policymakers to enhance manufacturing output and support economic development through the import of embodied technologies.

3. Methodology and Data

3.1 Model Specification

To examine the connection between imported capital goods and manufacturing output, our research develops a model based on the import-led growth hypothesis, which posits that in a country reliant on imports, the growth in manufacturing output is significantly influenced by the imported capital goods, in addition to factors such as inflation rate, financial development, and trade openness. This relationship can be articulated in the following manner.

$MO = f(ICG, INF\ FD, TO)$...(1)

In the relationship discussed, MO refers to the value added by manufacturing, ICG stands for the volume of imported capital goods, INF signifies the rate of inflation, FD indicates the level of financial development, and TO denotes the degree of trade openness. When analyzing how imported capital goods affect manufacturing output, we take into account exogenous factors such as inflation, financial development, and trade openness. The incorporation of inflation as a variable for explanation is essential since domestic prices can influence manufacturing output. An increase in prices may raise production costs, which can restrict manufacturing output; therefore, inflation can have a detrimental effect on manufacturing output. Financial development is considered an explanatory factor as private sector development is ensured by regular credit flow through proper financial development, which could positively influence manufacturing output. In addition, trade openness ensures the rapid trade mechanism that facilitates exports and imports; as an import-dependent economy, trade openness could negatively influence manufacturing growth if more consumer goods import can limit the country's manufacturing performance. The econometric relationship between imported capital goods and manufacturing output can be written as follows.

$$MO_t = \alpha_0 + \alpha_1 ICG_t + \alpha_2 INF_t + \alpha_3 FD_t + \alpha_4 TO_t + \varepsilon_t \text{ ....(2)}$$

In the econometric model, MO represents manufacturing value added as a percentage of GDP, ICG refers to imported capital goods as a percentage of GDP, INF denotes the inflation rate based on the consumer price index, FD indicates credit to the private sector as a percentage of GDP to measure financial development, and TO represents trade as a percentage of GDP for trade openness. The percentage format helps mitigate issues of heterogeneity or outliers.

3.2 Methods

In econometric analysis, we first conduct stationarity tests to assess the integration order of variables. Our study employs the augmented ARDL model to explore the relationship between imported capital goods and manufacturing output, requiring mixed orders of integration (I(0) and I(1)) but not I(2). We use the ARDL bounds test to check for long-run relationships, followed by an error correction method to analyze short-run dynamics. Various diagnostic tests validate the ARDL findings, and frequency domain causality analysis determines causality direction. Finally, we apply the dynamic ARDL simulation technique to explore counterfactual shocks.

3.2.1 Unit Root Tests

To assess the stationarity of the variables included in the research, we utilize several tests: the augmented Dickey-Fuller (ADF) test, the Dickey-Fuller generalized least squares (DF-GLS) test, the Phillips-Perron (PP) test, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and the Zivot and Andrews test. The ADF test is performed by enhancing the unit root test with the addition of a lagged difference of the dependent variable to address any serial correlation. The DF-GLS test proceeds after trend removal of the series through generalized least squares and subsequently applies the ADF test to identify the unit root. This approach is useful for de-meaning the data to account for any trends. In contrast, the PP test evaluates the unit root while considering robust standard errors to manage serial correlation. The KPSS test is employed to examine stationarity by adopting an alternative unit root hypothesis instead of the null hypothesis, allowing that the absence of a unit root may not unequivocally demonstrate stationarity. In some cases, the time series could be trend stationary. To identify any structural breaks within the variables, the Zivot and Andrews test is utilized, which checks for a unit root in the context of potential structural breaks and serial correlations in the time series data.

3.2.2 Augmented ARDL Bounds Test Approach

Our research utilizes the augmented ARDL bounds test method to investigate the presence of cointegration among the variables identified by McNown et al. (2018). One key benefit of the ARDL model in analyzing cointegration is its capability to accommodate mixed orders of integration in the series data, specifically I(0) or I(1), without the necessity for uniformity in their order of integration. Nonetheless, this model is not suitable if any series data is integrated of the second order, I(2). Additionally, the advantage of the ARDL model is its ability to provide more reliable results, even with a limited number of observations (Haug, 2002). As there is no level relationship between the independent and dependent variables, this model avoids facing any endogeneity issues. Moreover, the optimal lag selection for the variables under study is derived from the best combination of lag orders produced by simulation techniques that can effectively deal with the endogeneity in the relationships among the variables (McNown et al., 2018). The ARDL model introduced by Pesaran et al. (2001) has been enhanced by McNown et al. (2018), which necessitates an additional t-test or F-test to assess the coefficients of the lagged independent variables. The model below has been defined to explore the cointegration between the variables in this study.

$$\Delta MO_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\Delta MO_{t-i} + \sum_{i=0}^{q} \alpha_{2i}\Delta ICG_{t-i} + \sum_{i=0}^{r} \alpha_{3i}\Delta INF_{t-i} + \sum_{i=0}^{l} \alpha_{4i}\Delta FD_{t-i} + \sum_{i=0}^{k} \alpha_{5i}TO_{t-i} + \beta_1 MO_{t-1} + \beta_2 ICG_{t-1} + \beta_3 INF_{t-1} + \beta_4 FD_{t-1} + \beta_5 TO_{t-1} + \varepsilon_t \text{ .... (3)}$$

In Equation (3), the difference operator is denoted by Δ, and ε_t represents the white noise error term. The coefficients for short-term dynamics are represented by α_{1i}, α_{2i}, α_{3i}, α_{4i}, α_{5i}, while β_1, β_2, β_3, β_4, β_5 signify the parameters of the long-run relationship. To assess cointegration, the bounds test approach examines the null hypothesis of no cointegration in the coefficients of the level relationship among variables, such as $H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$. According to Pesaran et al. (2001), the F-test checks the significance of the long-run relationship, while the t-test evaluates the significance of the lagged dependent variable's coefficients. Both tests assume the dependent variable is integrated of the first order, I(1), and follow a non-standard distribution under the null hypothesis of no relationship among I(0) or I(1) variables. The F-test and t-test may not adequately confirm the cointegrating relationship due to degenerate cases. To address this, McNown et al. (2018) introduced an additional t-test or F-test for the lagged independent variables to aid in identifying the cointegrating relationship within the ARDL approach suggested by Pesaran et al. (2001). The augmented ARDL approach requires these three tests to confirm cointegration and resolve degenerate cases. The critical bounds for the tests are provided by Pesaran et al. (2001) and Sam et al. (2019), and the null hypothesis of no cointegration can be rejected if the F and t-test values exceed their upper critical bounds.

After confirming cointegration, we implement the error correction model to evaluate the short-term dynamics. The error correction model can be expressed in the following way.

$$\Delta MO_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\Delta MO_{t-i} + \sum_{i=0}^{q} \alpha_{2i}\Delta ICG_{t-i} + \sum_{i=0}^{r} \alpha_{3i}\Delta INF_{t-i} + \sum_{i=0}^{l} \alpha_{4i}\Delta FD_{t-i} + \sum_{i=0}^{k} \alpha_{5i}TO_{t-i} + \gamma ECT_{t-1} + \varepsilon_t \text{ .... (4)}$$

In the error correction model outlined in Equation (4), the error correction term coefficient γ reflects the adjustment from short-term imbalances to long-term equilibrium, ranging from -1 to 0. A statistically significant ECT coefficient of 0 indicates no adjustment in the following year due to current shocks, while a value of -1 signifies complete adjustment within that year.

3.2.3 Diagnostic Checks

Additionally, our research utilizes various diagnostic tests to assess the stability of the model. The Breusch-Godfrey LM test is used to address the issue of serial correlation, while the Breusch-Pagan-Godfrey test and ARCH test are employed to investigate the problem of heteroscedasticity. We apply the Ramsey RESET test to evaluate whether the model is appropriately specified, and we conduct the Jarque-Bera test to assess the normality of the residuals. This analysis includes the CUSUM test and CUSUM squares test to evaluate the structural stability of the model.

3.2.4 Frequency Domain Causality Analysis

We employ frequency-domain causality analysis instead of time-domain causality analysis to establish the causal link between the variables. The spectral causality test, created by Breitung and Candelon in 2006, builds on the earlier work of Geweke (1982) and Hosoya (1991). The primary distinction between the time-domain and frequency-domain methods is that the time domain reveals when a particular change takes place in the time series. Conversely, the frequency domain evaluates the size of a specific change within the time series. In brief analyses, serial patterns can be crucial factors, and the frequency domain allows for the exclusion of these fluctuations. Additionally, the frequency domain causality method permits the exploration of nonlinear and causal cycles, including causal relationships at both high and low frequencies (Gokmenoglu et al., 2019).

3.2.5 Novel Dynamic ARDL Simulation Technique

Alongside the augmented ARDL model, this study employs the dynamic ARDL simulation technique to explore the connection between imported capital goods and manufacturing output. Implementing simulation in the ARDL methodology necessitates that the dependent variable is strictly stationary at the first difference, indicating that the dependent variable is I(1) rather than I(0). The model can include explanatory variables of mixed order of integration, either I(0) or I(1). Nevertheless, these variables should not exhibit any structural breaks and should not have issues with autocorrelation and heteroscedasticity.

The novel dynamic ARDL simulation model can be written for our analysis according to Jordan and Philips (2018) and by following Udeagha and Ngepah (2022) as follows.

$$\Delta MO_t = \alpha_0 + \beta_0 MO_{t-1} + \beta_1 \Delta ICG_{t-1} + \delta_1 ICG_{t-1} + \beta_2 \Delta INF_{t-1} + \delta_2 INF_{t-1} + \beta_3 \Delta FD_{t-1} + \delta_3 FD_{t-1} + \beta_4 \Delta TO_{t-1} + \delta_4 TO_{t-1} + \varepsilon_t \quad (5)$$

The short-term behavior and the long-term relationship involving the error correction term are analyzed using 5000 simulations in the dynamic ARDL framework via an error correction method, with parameter vectors adhering to a multivariate normal distribution. The error correction coefficient is estimated to range from -1 to 0, indicating that the innovative simulation technique has identified the long-term equilibrium resulting from short-term dynamic adjustments. The dynamic ARDL simulation generates a graphical representation of counterfactual analysis by illustrating the effects of positive and negative shocks or variations of the independent variables on the dependent variable's behavior. More specifically, the response of the dependent variable to the explanatory variables is quantified and displayed through a graphical illustration, showing how alterations (both positive and negative) in the independent variables influence the response of the dependent variable.

3.3 Data and Variables

This research employs historical data from the period of 1991 to 2022 to explore the relationship between imported capital goods and manufacturing output in Bangladesh. The analysis begins in 1991, as this marks the onset of significant financial and trade liberalization in Bangladesh during the 1990s. The study identifies the manufacturing value added to GDP ratio (MO) as the dependent variable and the imported capital goods to GDP ratio (ICG) as the primary explanatory variable. In addition to these, our study incorporates other control variables such as inflation (INF), financial development (FD), measured by the credit to the private sector to GDP ratio, and trade openness, assessed through the trade to GDP ratio. The empirical analysis data for MO, INF, FD, and TO were sourced from the World Bank database, while data on ICG was obtained from the Bangladesh Bank database. A summary of the variables is provided in Appendix Table-1.

In examining the connection between the study variables, our research evaluates all indicators in terms of their ratios or rates. This approach has contributed to reducing the impact of outliers and the variability within the data series. The graphical representation of the variables is illustrated in Appendix Figure 1, which presents the time plots. This visual depiction indicates that the variables being investigated do not exhibit significant structural breaks. Table 1 provides the descriptive statistics for the study variables. The descriptive characteristics reveal that the mean and median of each variable are relatively close, and their skewness and kurtosis values generally fall between -2 and +2. The normality assumption, tested through the Jarque-Bera test for each variable, indicates that the observations originate from a normal distribution, as the probability value does not reject the null hypothesis of normality.

Table 1: Descriptive Statistics

	MO	ICG	INF	FD	TO
Mean	16.4548	4.5090	6.1437	30.7211	32.5372
Median	15.9071	4.3261	5.9043	31.6042	30.6669
Maximum	21.7648	8.4495	11.3951	44.4069	48.1109
Minimum	13.9871	1.6115	2.00717	14.5455	18.8898
Std. Dev.	2.5315	1.9299	2.2243	9.9650	7.9944
Skewness	1.0047	0.2041	0.11126	-0.1964	0.4270
Kurtosis	2.5664	1.9533	2.9702	1.5492	2.2488
Jarque-Bera	5.6351	1.6827	0.0672	3.0119	1.7248
Probability	0.0597	0.4311	0.9669	0.2218	0.4221
Observations	32	32	32	32	32

Source: Author's Estimation using E-views 10.

4. Empirical Results

4.1 Results of Unit Root Tests

We assess the order of integration of study variables using various unit root tests. For the augmented ARDL approach, a mixed order of integration is necessary, and no variables are integrated second order. Results from ADF, DF-GLS, PP, KPSS (without breaks), and Zivot & Andrews (with breaks) tests are shown in Table 2. All series are integrated at their first difference, except the INF series, which is stationary at the level under the KPSS test. The Zivot and Andrews test indicates the series is stationary with structural breaks late in the period, suggesting no endogeneity issues in the relationship between the variables. Consequently, we can investigate the link between imported capital goods and manufacturing output using the augmented ARDL bounds test as indicated by McNown et al. (2018).

Table 2: Results of Unit Root Tests

Variables	ADF test		DF-GLS test		PP test		KPSS test	
	Level	First Difference	Level	First Differ-ence	Level	First Differ-ence	Level	First Difference
MO	0.1269	-5.5864***	0.2891	-5.6372***	0.9678	-5.5870***	0.6061**	0.2142
ICG	-1.5309	-4.3953***	-1.0431	-4.4517***	-1.5302	-3.8112***	0.4755**	0.1270
INF	-4.0194***	-7.4497***	-4.0721***	-6.4537***	-4.0491***	-10.6475***	0.2416	0.5000
FD	-1.2684	-5.9156***	-0.4104	-5.2180***	-1.2844	-5.8904***	0.5850**	0.2430
TO	-1.9434	-4.5186***	-1.3589	-4.5209***	-1.9434	-4.4643***	0.3708**	0.1708

Zivot & Andrews test

Variables	Level		First Difference	
	t-statistic	Break Point	t-statistic	Break Point
MO	-4.9215***	2016	-3.5973**	2016
ICG	-4.4020***	2015	-5.2556**	2013
INF	-5.2770***	2004	-3.3132**	2003
FD	-4.0440***	2016	-7.6798***	2013
TO	-4.7091***	2016	-5.0397**	2014

Source: Author's Estimation Using E-views 10.

Note: '***', '**', and '*' Denote Significance at the 1%, 5%, and 10% Levels, Respectively.

4.2 Augmented ARDL Model Estimation

4.2.1 Augmented Bounds Test Analysis

Prior to conducting the augmented bounds test for cointegration, the ideal lag lengths for the ARDL model were determined using the Akaike Information Criterion (AIC). The optimal lag orders were identified from 2500 different regression combinations of the variable lag lengths, with the combination yielding the lowest AIC value indicating the best lag lengths for the ARDL model. The least favorable 20 combinations of the variable lags are displayed in Appendix Figure 2, while the lowest AIC value signifies that the optimal lag orders are ARDL (3,4,2,4,4).

The anticipated outcomes of the augmented bounds test are shown in Table 3; it is evident that the computed F statistic for evaluating the joint hypothesis and the t-statistic for the lagged dependent variables under the null hypothesis of no long-run cointegration surpass the upper bound of the critical value recommended by Pesaran et al. (2001) at both 1% and 10% significance levels. Since the calculated values of the F and t statistics reject the null hypothesis of no level relationship, this supports the presence of long-run cointegration among the variables. While the overall F-test and t-test on lagged dependent variables confirm long-run cointegration, there is a possibility that certain degenerated cases of the long-run relationship may occur in practice, as identified by Pesaran et al. (2001). To address the issue of degenerated cases, an additional t-test on lagged independent variables has been conducted under the null hypothesis of no cointegration, as suggested by McNown et al. (2018). The calculated t statistic for the lagged independent variables surpasses the critical upper bound established by Narayan (2005) and Sam et al. (2019) at a 5% significance level, which further confirms the existence of long-run cointegration and mitigates any concerns regarding degenerated cases in the relationship among the study variables.

Table 3: Results of Augmented ARDL Bounds Test

Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	7.949***	10%	2.25	3.52
(joint hypothesis testing)		5%	2.86	4.01
		1%	3.74	5.06
Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-3.743*	10%	-2.57	-3.66
(on lagged dependent variables)		5%	-2.86	-3.99
		1%	-3.43	-4.60
Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-4.384**	10%	-2.57	-3.66
(on lagged independent variables)		5%	-2.86	-3.99
		1%	-3.43	-4.60

Source: Author's Estimation Using E-views 10.
Note: '***', '**', and '*' Denote Significance at the 1%, 5%, and 10% Levels, respectively.

4.2.2 The Long-run Cointegration Analysis

Once the augmented bounds test verifies the presence of a long-run relationship, we proceed to estimate the long-run cointegration among the variables. The coefficients estimated for the long-run relationship are presented in Table 4. These findings indicate that imported capital goods have a significant (at the 5% level) positive relationship with manufacturing output, while trade openness shows a significant (at the 1% level) negative correlation with manufacturing output. Conversely, inflation and financial development demonstrate insignificant negative and positive connections with manufacturing output. In the long run, the link between imported capital goods and manufacturing output suggests that a 1 percent increase in the ratio of imported capital goods to GDP is associated with an over 2 percent increase in the manufacturing value added to GDP ratio. Similarly, in the long run, a 1 percent rise in the trade to GDP ratio leads to a 0.45 percent decrease in manufacturing value added to GDP ratio. Although the relationships between inflation and financial development with manufacturing output are not statistically significant, the anticipated signs of these two factors indicate a positive economic effect on manufacturing output in the long-term relationship.

Table 4: Results of Long-run Relationship

Dependent Variable	Regressors	Coefficient	Std. Error	t-Statistic	Prob.
	ICG(-1)	2.1932**	0.6784	3.2329	0.0178
Δ(MO)	INF(-1)	-0.0740	0.2435	-0.3042	0.7712
	FD(-1)	0.0110	0.1029	0.1078	0.9176
	TO(-1)	-0.4581***	0.1122	-4.0814	0.0065

Source: Author's Estimation Using E-views 10.
Note: '***', '**', and '*' Denote Significance at the 1%, 5%, and 10% Levels, Respectively.

4.2.3 Short-run Dynamics and Error Correction Analysis

The short-run dynamics of the augmented ARDL model are now estimated through the error correction method, with the estimated coefficients for short-run relationships and the error correction presented in Table 5. The results indicate that the coefficient of the error correction term (ECT) is negative and significant at the 1% level. This suggests that there is a consistent adjustment from short-run disequilibrium towards long-run stability. Specifically, the ECT coefficient highlights that 57 percent of the shocks or imbalances are corrected within a year, signifying that shocks from prior years have significantly converged to the subsequent year. In the short term, the influences of imported capital goods, inflation, and financial development adversely affect manufacturing output, whereas trade openness positively contributes to manufacturing output. The significant coefficients of the short-run dynamics underscore that an appropriate short-run linkage in the augmented ARDL framework aligns with the long-term cointegration among the variables.

Table 5: Results of Short-run Dynamics and Error Correction Estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Δ(MO(-1))	-0.1725	0.1218	-1.4159	0.2066
Δ(ICG)	0.3796*	0.1838	2.0645	0.0845
Δ(ICG(-1))	-1.4279***	0.2315	-6.1678	0.0008
Δ(ICG(-2))	-1.3341***	0.2332	-5.7199	0.0012
Δ(ICG(-3))	-1.3349***	0.2135	-6.2518	0.0008
Δ(INF)	0.0692	0.0395	1.7523	0.1303
Δ(INF(-1))	0.0794	0.0421	1.8827	0.1087
Δ(INF(-2))	-0.0496**	0.0355	-1.3991	0.0113
Δ(FD)	-0.1889***	0.0421	-4.4798	0.0042
Δ(FD(-1))	-0.3119***	0.0562	-5.5419	0.0015
Δ(FD(-2))	-0.2526***	0.0549	-4.5979	0.0037
Δ(FD(-3))	-0.2018***	0.0465	-4.3339	0.0049
Δ(TO)	-0.1306**	0.0399	-3.2713	0.0170

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Δ(TO(-1))	0.2740***	0.0487	5.6265	0.0013
Δ(TO(-2))	0.2477***	0.0572	4.3251	0.0050
Δ(TO(-3))	0.1739***	0.0406	4.2783	0.0052
ECT/CointEq(-1)*	-0.5784***	0.0613	-9.4302	0.0001

Source: Author's Estimation Using E-views 10.
Note: '***', '**', and '*' Denote Significance at the 1%, 5%, and 10% Levels, Respectively.

4.3 Diagnostic Tests of the Augmented ARDL Model

The robustness of the ARDL model has been affirmed through various diagnostic tests, including autocorrelation, normality, heteroscedasticity, model specification, and structural stability tests. Results shown in Appendix Table 2 indicate that the Breusch-Godfrey test reveals no autocorrelation in the residuals. The Breusch-Pagan-Godfrey and ARCH tests confirm the absence of heteroscedasticity. The Jarque-Bera test shows the residuals are normally distributed. The Ramsey RESET test indicates no specification error. The structural stability tests, depicted in Appendix Figure 3, confirm that the recursive residuals remain within the 5% significance level boundaries, indicating structural stability without breaks in the long-term relationship. Overall, these diagnostic checks confirm the robustness and consistency of the augmented ARDL model in both long-run and short-run coefficients throughout the study period.

4.5 Results of Frequency Domain Causality

The relationship between the variables is analyzed using frequency domain causality analysis (Breitung & Candelon, 2006), with the findings presented in Table 6. The causative link between imported capital goods and manufacturing output is statistically significant in both the short and long term. Conversely, the relationship between financial development, trade openness, and manufacturing output also shows statistical significance in the long run. This causality assessment indicates that imported capital goods exert a strong causal impact on manufacturing output within the frequency domain, highlighting the robust causality that flows from imported capital goods to manufacturing output both in the short run and the long run.

Table 6: Results of Frequency Domain Causality

Variable	Long-term	Medium-term	Short-term
	Frequency, ω = 0.05	Frequency, ω = 1.5	Frequency, ω = 2.5
	Wald test statistic	Wald test statistic	Wald test statistic
ICG causes MO	6.9694**	2.2295	4.6799*
INF causes MO	0.5396	0.4266	0.3249
FD causes MO	16.1020***	0.9313	1.0120
TO causes MO	5.7590*	0.6019	0.4559

Source: Author's Estimation Using Stata 17.
Note: '***', '**', and '*' Denote Significance at the 1%, 5%, and 10% Levels, Respectively.

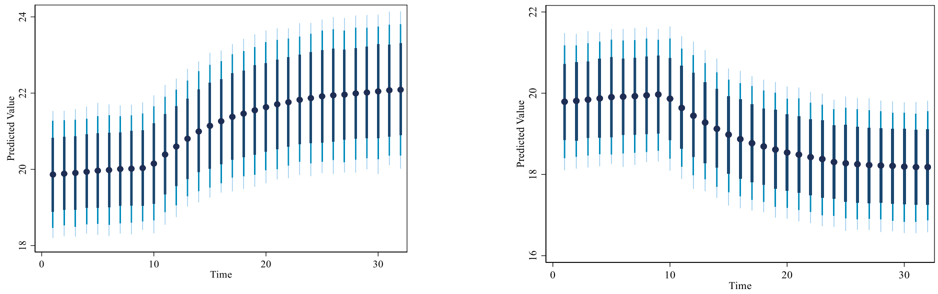
4.6 Results of Counterfactual Analysis

The counterfactual analysis utilizes a new dynamic ARDL simulation method to examine both the positive and negative impacts of the independent variable on the dependent variable while maintaining the effect of other control factors on the dependent variable unchanged. This analysis primarily centers on how the dependent variable responds to the positive and negative shocks of the independent variables.

Figure-1 depicts the effects of changes in imported capital goods on manufacturing output. Graph (a) shows that a positive change in imported capital goods enhances manufacturing output over time, particularly in the long run. In contrast, graph (b) illustrates that a decrease in imported capital goods leads to a decline in manufacturing output. Therefore, the long-term benefits of imported capital goods on manufacturing output are evident in Bangladesh. The dot in the graphs indicates the predicted value, while the dark to light blue lines represent confidence intervals of 75%, 90%, and 95%.

Figure 1: Response of Manufacturing Output to Imported Capital Goods

(a) Positive shocks of ICG to MO (b) Negative shocks of ICG to MO

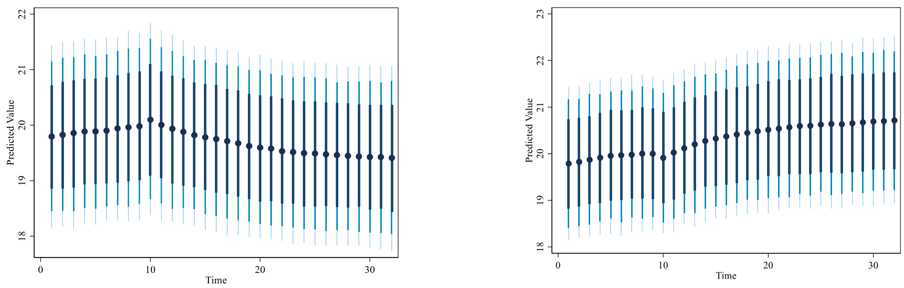


Source: Author’s Estimation Using Stata 17.

Figure-2 illustrates the impact of counterfactual inflation shocks on manufacturing output. Graph (a) shows that a 1% positive inflation shock increases manufacturing output in the short term but decreases it in the long term. Conversely, graph (b) reveals that negative inflation shocks adversely impact manufacturing output, while positive shocks boost it over the study period. Thus, inflation, whether positive or negative, has both short- and long-term effects on manufacturing output. The dot in the graphs indicates the predicted value, with the dark to light blue lines representing 75%, 90%, and 95% confidence intervals.

Figure 2: Response of Manufacturing Output to Inflation

(a) Positive shocks of INF to MO (b) Negative shocks of INF to MO

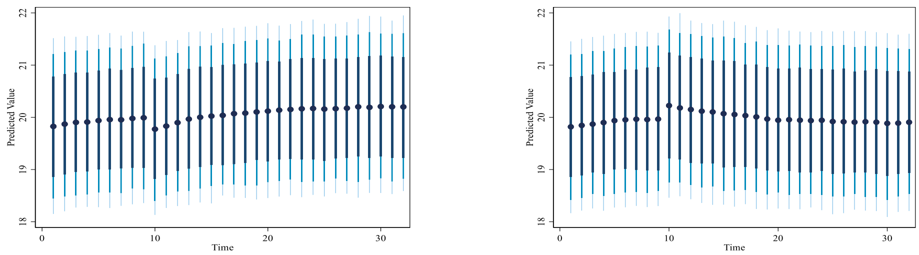


Source: Author’s Estimation Using Stata 17.

Figure-3 illustrates the impact of financial development, measured by the credit to private sector to GDP ratio, on manufacturing output through counterfactual shocks. The graphs show that both positive and negative changes in financial development affect manufacturing output. An increase in financial development boosts manufacturing output in both the short and long run, while adverse shocks have a negative effect. Specifically, a 1 percent increase in the credit to GDP ratio raises manufacturing output, while a decrease lowers it. The dots represent predicted values, and the lines indicate confidence intervals of 75%, 90%, and 95%.

Figure 3: Response of Manufacturing Output to Financial Development

(a) Positive shocks of FD to MO (b) Negative shocks of FD to MO

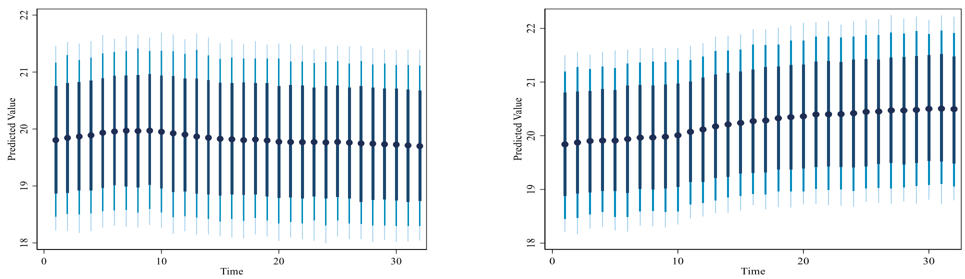


Source: Author's Estimation Using Stata 17.

The effects of changes in trade openness on manufacturing output are illustrated in Figure-4 from counterfactual analysis. The first graph (a) shows that a 1% increase in trade openness reduces manufacturing output in both the short and long run. Conversely, a decrease in trade openness positively impacts manufacturing output in the short and long run. This suggests that while higher trade openness may lower manufacturing output in Bangladesh, lower trade openness could enhance it. The dots represent predicted values, while the dark blue to light blue line indicates confidence intervals of 75%, 90%, and 95%.

Figure 4: Response of Manufacturing Output to Trade Openness

(a) Positive shocks of TO to MO (b) Negative shocks of TO to MO



Source: Author's Estimation Using Stata 17.

The results of the econometric analysis, including the augmented ARDL analysis, indicate that there is a positive relationship between imported capital goods and manufacturing output over the long term. Conversely, in the short term, imported capital goods produce varying effects on manufacturing output. The frequency domain causality analysis shows that there is a significant causal relationship between imported capital goods and manufacturing output in both the short and long run. The counterfactual analysis demonstrates that imported capital goods positively impact manufacturing output in the long term. However, in the short term, the effect of imported capital goods on manufacturing output is moderate but on an upward trend. Our research findings align with previous studies that highlight a positive connection between imported capital goods and manufacturing output (Herrerias & Orts, 2011; Hye et al., 2013; Maitra, 2020; Wahab et al., 2016). Nonetheless, regarding the lack of a significant relationship between imports and economic growth, our study's results differ from those found in earlier research (Hossain et al., 2009; Paul, 2011).

5. Conclusion and Policy Recommendations

This study examines the relationship between imported capital goods and manufacturing output in Bangladesh. The augmented ARDL bounds testing approach shows a long-run positive association between the two factors. The error correction mechanism indicates a short-run convergence toward long-run cointegration, confirming the short-term relationship. Additionally, frequency domain causality analysis reveals a causal linkage in both short and long-term periods. Counterfactual analysis using the dynamic ARDL simulation approach further supports that imported capital goods positively impact manufacturing output in the long run.

Moreover, our study explores the relationship between imported capital goods and manufacturing output in Bangladesh, including factors like inflation, private sector credit to GDP, and trade to GDP ratio. The results indicate that inflation negatively affects manufacturing output both in the long and short run, while financial development positively influences output in the long run. Conversely, trade openness has a long-term negative impact on manufacturing output in Bangladesh.

The analysis indicates that in a technology-constrained economy, imported capital goods boost long-term manufacturing output by providing essential technology and know-how, supporting the import-led growth hypothesis (Li et al., 2021; Liao et al., 2023; Panta et al., 2022; Sharma et al., 2023). Conversely, inflation negatively impacts manufacturing output by raising production costs. Furthermore, financial development positively correlates with manufacturing output, as consistent credit flow to the private sector can enhance production in Bangladesh. However, increasing imports of consumer goods, rather than capital goods, can reduce demand for domestically produced goods, contributing to a long-term negative relationship between trade openness and manufacturing output in the country.

Our research recommends key policy enhancements to boost manufacturing output via imported capital goods. Policymakers should establish effective import policies and best practices to support manufacturing growth and economic development. It's essential to invest in training the labor force to utilize imported capital effectively. Additionally, implementing price stability measures can help control inflation and support long-term manufacturing growth. Finally, reducing import dependency through domestically produced goods will strengthen the manufacturing sector and contribute to overall economic growth.

Nonetheless, our research has certain limitations. Due to the lack of a comprehensive data span, we rely on a limited dataset to explore the connection between imported capital goods and manufacturing output in Bangladesh. Utilizing various data sets along with additional explanatory variables could yield more accurate and relevant results. Consequently, further investigations are recommended using alternative methodologies and other control variables with diverse data collections, which may help address the gaps in the current research.

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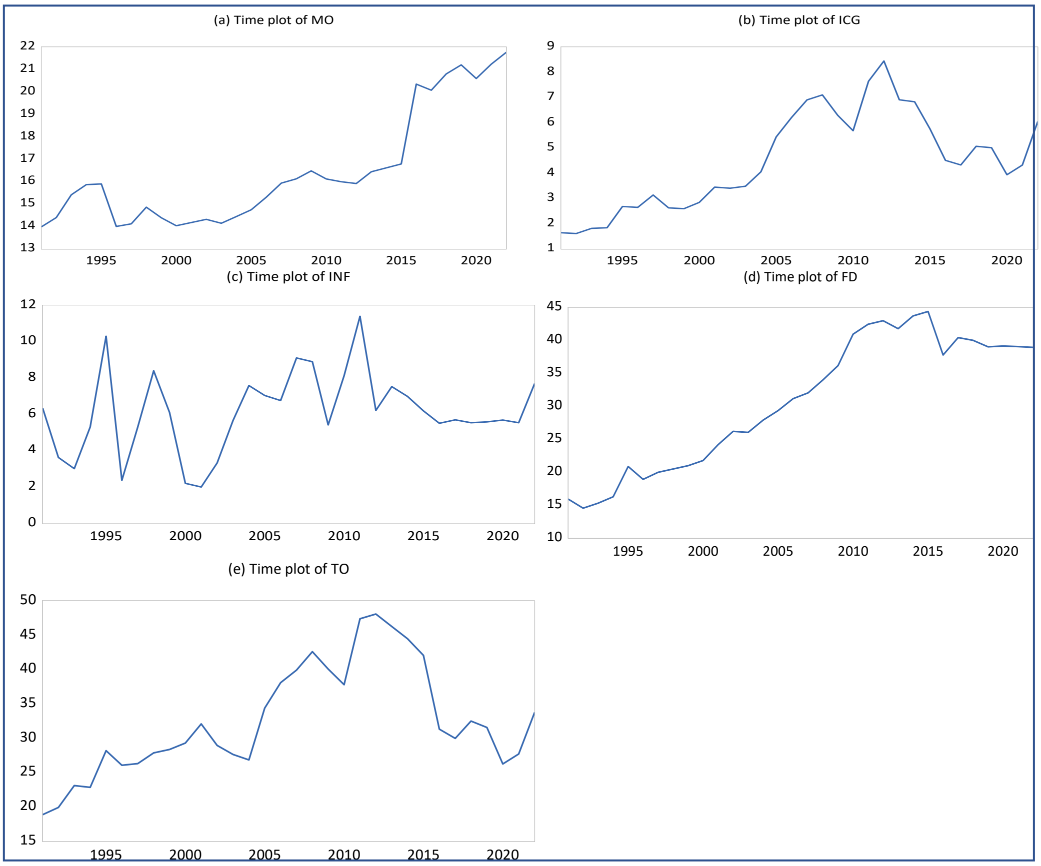
Appendices

Appendix Table 1: Variables and Data Source

Variable	Name	Explanation	Data Source
MO	Manufacturing output	Manufacturing value added as a percentage of GDP	World Bank
ICG	Imported capital goods	Imported capital goods as a percentage of GDP	Bangladesh Bank
INF	Inflation	Annual inflation rate measured by the change in consumer price index	World Bank
FD	Financial development	Domestic credit to the private sector as a percentage of GDP	World Bank
TO	Trade openness	Trade as a percentage of GDP	World Bank

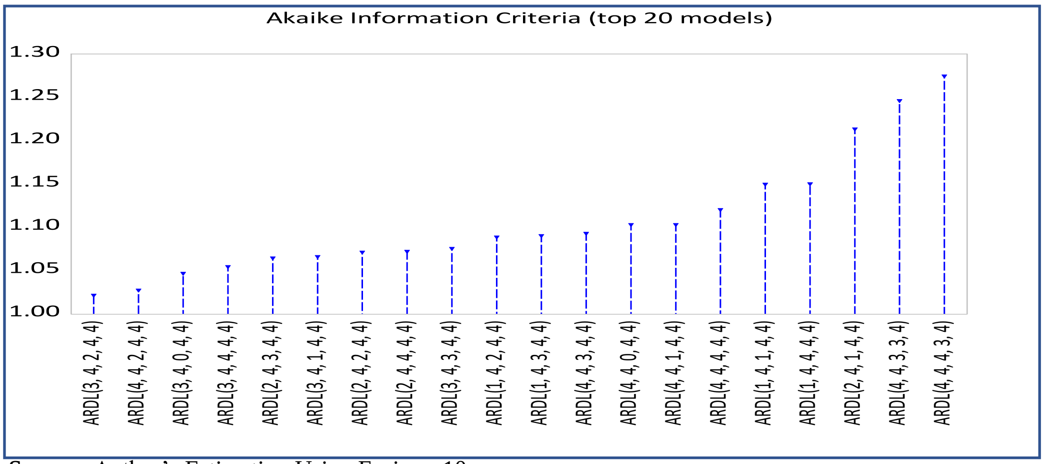
Source: Author's Compilation.

Appendix Figure 1: Time Plot of Different Study Variables, (a)-(e)



Source: Author's estimation using E-views 10.

Appendix Figure 2: Optimal Lag Length Selection



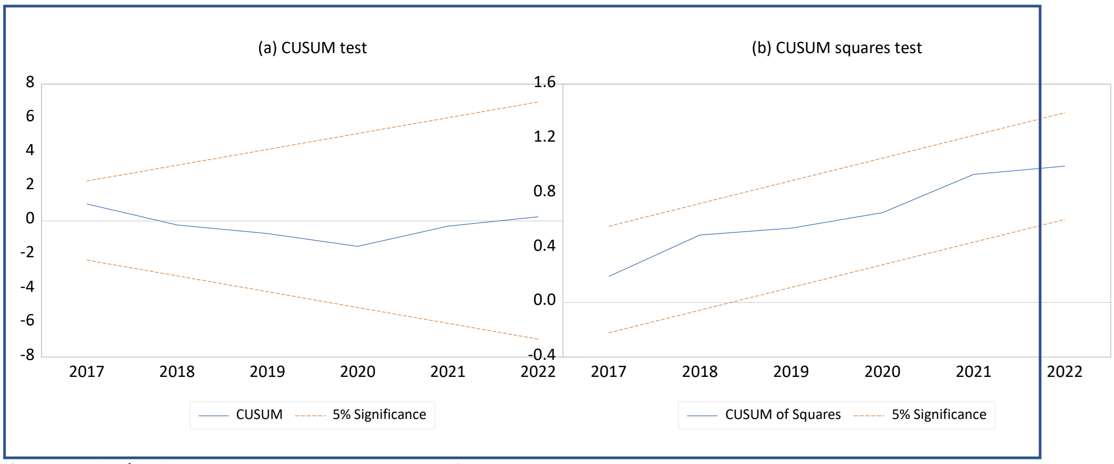
Source: Author's Estimation Using E-views 10.

Appendix Table 2: Results of Diagnostic Tests of the Augmented ARDL Model

Test	Test Statistic	Prob.
Breusch-Godfrey Serial Correlation LM Test	F-statistic = 0.0811	0.9224
Jarque-Bera Normality Test	J-B = 0.0429	0.9787
Breusch-Pegan-Godfrey for Heteroscedasticity	F-statistic = 1.7076	0.1552
ARCH Test for Heteroscedasticity	F-statistic = 0.7926	0.3812
Ramsey RESET Test	F-statistic = 0.0785	0.7821

Source: Author's Estimation Using E-views 10.

Appendix Figure 3: (a) CUSUM Test, (b) CUSUM Squares Test



Source: Author's Estimation Using E-views 10.