Impact of climate variability on Myanmar's agricultural, total exports, and textile industry: Asymmetric and dynamic multipliers

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ABSTRACT – REZUMAT

Impact of climate variability on Myanmar's agricultural, total exports, and textile industry: Asymmetric and dynamic multipliers

Climate change brings uncertainty and instability to ecosystems, economies, and global supply chains. It also significantly influences the total export value of countries that heavily rely on agriculture for economic growth. This study investigates the effects of climate variability on Myanmar's agricultural and total exports. This study uses the nonlinear autoregressive distributed lag (NARDL) approach for the annual data from 1990 to 2021. This study finds that rainfall negatively affects agricultural and total exports. Increasing rainfall leads to declining agricultural exports, whereas decreasing rainfall enhances total exports in the long run. Decreasing rainfall declines agricultural exports, while increasing rainfall diminishes total exports in the short run. Carbon emissions (CO_2) adversely affect agricultural and total exports in both runs. However, temperatures positively impact agricultural and total exports in both runs. In controlled variables, increased GDP has a positive impact on both agricultural and total exports. The textile and garment industry in Myanmar is perceived as an economic sector that is mainly export-oriented. Agricultural production contributes significantly to agricultural exports, which enhances total exports. This study offers new policy insights to adapt and mitigate climate change's influence on Myanmar's export sectors.

Keywords: *climate variability, textile field, garment industry, agricultural export, total export, NARDL, Myanmar, agricultural commodities*

Impactul variabilității climatice asupra agriculturii, exporturilor totale și industriei textile din Myanmar: Multiplicatori asimetrici și dinamici

Schimbările climatice aduc incertitudine și instabilitate ecosistemelor, economiilor și lanțurilor globale de aprovizionare. De asemenea, acestea influențează valoarea totală a exporturilor țărilor care se bazează în mare măsură pe agricultură pentru creșterea economică. Acest studiu investighează efectele variabilității climatice asupra exporturilor agricole și totale ale Myanmarului. Acest studiu empiric utilizează modelul Nonlinear Autoregressive Distributed Lag (NARDL) pentru datele anuale din perioada selectată 1990–2021. Această cercetare constată că precipitațiile afectează negativ exporturile agricole și totale. Creșterea precipitațiilor conduce la scăderea exporturilor agricole, în timp ce scăderea precipitațiilor sporește exporturile totale pe termen lung. Scăderea precipitațiilor scade exporturile agricole, în timp ce creșterea precipitațiilor diminuează exporturile totale pe termen scurt. Emisiile de carbon (CO_2) afectează negativ exporturile agricole și totale în ambele sensuri, respectiv pe termen scurt și pe termen lung. Cu toate acestea, temperaturile au un impact pozitiv asupra exporturilor agricole și totale în ambele cazuri. În variabilele controlate, creșterea PIB-ului are un impact pozitiv atât asupra exporturilor agricole, cât și asupra celor totale. Industria textilă și de îmbrăcăminte din Myanmar este percepută ca un sector economic orientat în principal spre export. Producția agricolă contribuie semnificativ la exporturile agricole, ceea ce sporește exporturile totale. Acest studiu oferă noi perspective politice pentru a adapta și a atenua influența schimbărilor climatice asupra sectoarelor bazate pe export din Myanmar.

Cuvinte cheie: *variabilitate climatică, domeniu textil, industrie de îmbrăcăminte, export agricol, export total, model NARDL, Myanmar, produse agricole*

INTRODUCTION

Climate change is triggering a new era of uncertainty and instability in ecosystems, economies, and global supply chains [1]. The changing climates include increasing variability, rising temperatures, shifting rainfall patterns, and a growing number of extreme climate occurrences [2]. It substantially impacts the agriculture sector, export and trade patterns, and economic activities of emerging and developing countries that heavily rely on commodity exports [3–5]. The nations are exposed to climate change when they depend on agriculture, natural resources, inadequate institutions, high poverty levels, and insufficient climate adaptation policies [6]. Climate change disrupts agricultural productivity through altered rainfall patterns and temperature extremes, leading to reduced crop yields. These effects negatively disturb the country's agricultural and total exports, where agriculture is vital to its export economy. Khan et al. [7] highlighted that climate variables' effects on a country's export sector have been substantial, primarily due to the increasing volatility in weather patterns. FAO [8] stated that it is crucial to prioritise strategies to safeguard business sectors against the consequences of climate change. Also, the United Nations enacted SDG 13, "climate action, to take urgent action to combat climate change and its impacts", aiming to address one of humanity's most pressing challenges. Therefore, understanding the impacts of climate variability on agri- and total exports in Myanmar goes beyond simple academic curiosity.

According to the Myanmar Garment Manufacturers Association, there has been a long-standing existence of the garment and textile industry in Myanmar, being one of the most prosperous and significant economic sectors. Moreover, the traditional garment and textile products are manufactured in authentic Myanmar artisan workshops by the Indigenous population, such as the following: Shan, Chin and Naga. Moreover, as a statistical approach, it is mentioned that over a decade, that is, between the years 1990 and 2001, "garment production increased from 2.5% of total exports in 1990 to 39.5% of exports in 2000", which means that it has become the most significant export industry in the state of Myanmar. In this regard, it is important to highlight the fact that Myanmar has one of a member state of the Association of Southeast Asian Nations, also known as ASEAN, since 23 July 1997. On the other hand, textiles represent the most important export products for the last period from ASEAN.

Currently, Myanmar faces difficulties because of the effects of the changing climate. Due to her susceptibility to floods and tropical cyclones, she is considered one of the most vulnerable countries to climate change globally [9]. This country has the highest vulnerability to economic impacts from climate change in the ASEAN regions [10]. In 2022, the country ranked second among 184 nations in the Global Climate Risk Index and eleventh among 191 nations in the INFORM Index for Risk Management. Floods, droughts, rising temperatures, heavy and sparse rainfall, and rising sea levels are the most significant threats in Myanmar [11]. Her most vulnerable sectors to climate change are agriculture, water resources, healthcare, forestry, coastal areas, and biodiversity [11]. Thus, the climate crisis could also impact Myanmar's agriculture and export dynamics regarding supply and demand. Climate change significantly squeezes the nation's export-dependent industries, which is particularly concerning for the country's economy [12].

Myanmar mainly exports agricultural commodities, minerals, and textiles for foreign income [13]. The textile and garment industry is one of the most important sectors in the emerging economy of Myanmar. The main export items are oil, gas, copper, wood, rice, pulses, seafood, clothing, and precious stones [13]. In 2022, the nation's export composition consisted primarily of mineral fuels, apparel and accessories, knit or crochet clothing, vegetables, cereals, fish, footwear, rubber articles, leather/animal gut articles, and fruits and nuts. These categories collectively accounted for 87.6% of Myanmar's global shipments [14]. This data highlights the economic importance of exports in the country. The agriculture sector, which accounts for 35.1 percent of Myanmar's total exports [15]. However, due to climate change, this sector may cause a loss in agricultural production, further affecting agri-export, which has a one-third share of total exports in Myanmar.

The climate crisis can potentially impact production activities and product supply chain disruptions [16]. The UNEP [17] stated that alterations in temperature and rainfall have reduced agricultural productivity, affecting food security and export volumes in Myanmar. The agricultural exports of Myanmar, such as rice, wheat, beans, and pulses, exhibit vulnerability to climate variations [18]. Severe rainfall for monsoon crops and drought for summer crops are Myanmar's most dangerous rainfall occurrences [19]. Hefty rainfall and severe weather can also disrupt transportation and extraction activities [16].

According to certain research studies [20], the industrial sector may experience indirect consequences because of climate change-induced disruptions in the supply chain. Hence, climate disruptions in export sectors can significantly influence a nation's foreign exchange reserves, balance of payments, and overall economic growth. The influence of climate factors on commerce and exports is a matter of great significance, not only for individual countries but also for the interconnected global society. Changing climates threaten production activities and supply chain stability, impacting the quality and quantity of exported products. So, this study explores the effects of climate variability on the export sectors and possible adaptation measures in Myanmar. It will provide insights into the path forward for the nation's climate-responsive exports.

Due to the high possible climate impacts on agriculture and export activities, we determined the link between climate variability and agri- and total exports in Myanmar using the nonlinear autoregressive distribution lag (NARDL). This method seizes the potential asymmetrical impacts of climate variables on the nation's exports, which need to be considered in the existing literature. The study first contributes to the current body of literature by exploring these asymmetrical impacts of temperature, rainfall, and CO_2 on agricultural and total exports in Myanmar. Second, we employ the NARDL method to enhance our understanding and application of knowledge in this field by using the data for 1990–2021. Third, as preliminary tests, we perform standard and structural break unit root tests [Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP)], BDS tests of nonlinearity, vector autoregressive (VAR) lag selection, the Wald test for long-run asymmetrical relation of variables, and bounds testing for cointegration. We also apply diagnostic analysis, stability checks, dynamic multiplier asymmetry, and the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) to verify the robustness of the study. Fourth, our findings can aid the government in creating policies to mitigate climate change impacts while encouraging economic development in Myanmar through export enhancement.

The rest of the sections are organised as follows: Section 2 presents a comprehensive analysis of the existing literature, providing a detailed overview of the current understanding of the relationship between climate variability and agri- and total exports, as well as the theoretical analysis. Section 3 outlines the data and methodology. Section 4 presents the results and discussions. Section 5 concludes with key findings and policy implications.

LITERATURE REVIEW

Empirical analysis

Based on prior literature, we analyse the interplay between climate variables and many countries' export performance, but the empirical literature on this issue is limited.

Vital et al. [21] indicated that rising temperature adversely impacts a nation's capacity to export agricultural commodities, leading to diminished crop productivity and output. It also significantly impacts export quality by affecting crop growth, pest incidence, water requirements, post-harvest conditions, and transportation logistics. So, unfavourable temperature changes have negatively affected the quality of exports and the availability of domestic intermediate goods [22]. Karlsson [23] analysed the restricted cubic spline (RCS) and found that an average temperature exceeding 25 degrees Celsius decreased about 0.22% in exports of the United States. In cold weather, each consecutive day with a temperature below –5 degrees Celsius reduced monthly exports by 0.21% compared to the reference temperature. Zhang and Li [24] applied a semi-parametric method and found a significant decrease in export quality as high-temperature days increased in China. Increasing temperatures intensify this negative impact, demonstrating that higher temperature significantly influences the export quality of newly entered goods, followed by departed goods. In contrast, goods under production are affected to a lesser extent. Jones et al. [25] investigated the correlation between temperature and exports, revealing that temperature has a detrimental effect on developing nations' economies. They determined that a 1-degree Celsius upsurge in temperature in a year causes an average reduction in export growth for developing nations, ranging from 2.0 to 5.7 percent. The temperature changes are more likely to affect exports and stable domestic spending than GDP [25].

Rainfall is a significant hydrological input for numerous countries, serving as a vital water resource upon which these nations strongly depend to foster economic development. Changes in rainfall patterns may impact crop productivity, leading to the exportation of agricultural goods. Olubunmi [26] stated that rainfall impacts productivity, exports, energy supply, transportation, agriculture, health, and work motivation. The maintenance of economies, production, crops, and export revenues in numerous nations heavily relies on the presence of constant rainfall. Jones et al. [25] indicated that minor rainfall impacts could stimulate increased exports from developing countries. Moreover, scholars argued that daily rainstorms may have a more detrimental impact on high-income nations than low-income ones. The manufacturing and service sectors, which form the foundation of developed economies, are more exposed to the effects of frequent heavy rainfall than the agricultural sector [27]. Heavy rainfall can also result in floods, which may cause the displacement of people and significant economic losses [28]. Bortz et al. [29] used the instrumental variable approach to study rainfall patterns, agricultural exports, and reserves in Argentina. The study showed that changes in rainfall adversely affected the economic development of nations that rely on exporting commodities. The link between the agriculture sector and rainfall suggests a causal relationship, implying that rainfall influences a country's exports through this mechanism. Bozzola [1] examined the influence of changing climates on the worldwide agri-food trade. Their findings revealed that a 5 mm rise in rainfall causes an average export value increase of 8.73% (1.77 billion USD).

Carbon dioxide (CO_2), one of the main components of GHGs, accounts for 76% of world emissions and causes pollution, leading to climate change [30, 31]. CO_2 arises from energy generation, specifically oil, coal, and gas combustion, for manufacturing resources and primary materials for the country's exports and economic growth [32]. The production and transportation of exchanged commodities and services released 8 billion metric tons of CO_2, about 25% of the total [33]. Increasing CO_2 has negatively impacted ecosystems, which are crucial for export sectors like agriculture and forestry [34]. Khan et al. [7] observed the link between CO_2 and Pakistan's agricultural export commerce. The authors indicated a negative correlation between CO_2 and agricultural exports, significantly influencing the country's economy. Accordingly, this negative association leads to a drop in the overall trade volume. Khan et al. [35] applied the common correlated effects mean group (CCEMG) to determine the effect of CO_2 on international trade for BRI countries. This study found that trade production has been significant because of the increase in CO_2 and the slowdown in countries' economic progress. [36] employed the vector autoregressive (VAR) to explore the link between CO_2 and economic factors in China. Among the economic factors, CO_2 has a causal, unidirectional link to export volume in China's eastern provinces.

Despite the insights provided by current literature, significant gaps still need to be addressed in assessing climatic variability's effects on agricultural and total exports. It requires understanding the nexus between temperature, rainfall, CO_2, and export performance to add to the present literature. More research is needed, particularly in Myanmar, grappling with significant challenges concerning climate change and its interactions. As the least developed nation, Myanmar requires this research endeavour to understand climate change's impacts and prepare for it. In contrast to the study into the effects of exports on environmental degradation, Myanmar is currently identifying the consequences of climate change and mitigating its effects. This research is vital in assessing the impact of climate change on Myanmar's export sectors and making policy recommendations to adapt and mitigate climate impacts that support sustainable economic growth. Expanding export-oriented activities that are resilient and adapted to changing climates will contribute to the country's economy. Lastly, the use of the advanced nonlinear model, NARDL, to investigate the effects of climate variability on agri- and total exports is still lacking, and this is the first such study in Myanmar.

Theoretical analysis

Climate variability, characterised by changes in temperature, rainfall patterns, and carbon emissions (CO_2), significantly impacts agricultural productivity. Given agriculture's central role in Myanmar's economy, it is crucial to understand how these climate factors influence agri- export and total exports. This theoretical analysis explores the climate variables' asymmetric effects on Myanmar's agri- and total export performance. Figure 1 illustrates the nexus between the studied variables.

Agriculture responses to temperature changes are often nonlinear [37]. Moderately increased temperature enhances crop growth, while extreme heat causes yield reductions due to heat stress and increased evapotranspiration [38]. Rainfall changes can lead to asymmetric impacts.

Drought conditions lead to water scarcity and reduced soil moisture, while heavy rains cause flooding, soil erosion, and nutrient leaching. Increased CO_2 boosts photosynthesis and water usage efficiency in certain crops, possibly leading to higher yields [39]. C3 plants, which are wheat, rice, soybeans, barley, oats, cotton, potatoes, tomatoes, and other broadleaf plants, generally respond positively to increased CO_2 levels.

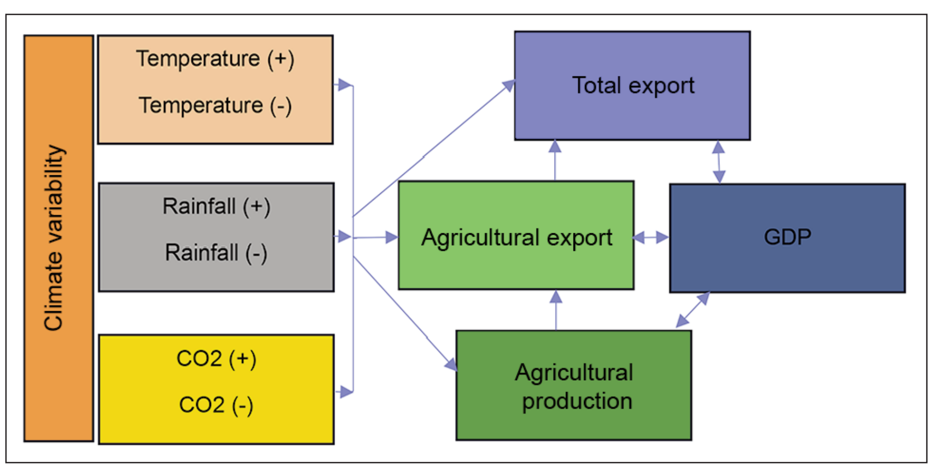

Fig. 1. Framework for the nexus between the studied variables

Besides, the CO_2 impact on crop yields is interlinked with temperature and rainfall changes. Higher CO_2 levels may partially mitigate the adverse effects of moderate heat stress on crop physiology, but may not offset the impacts of extreme heat or drought [40]. Therefore, climate variability directly influences agricultural productivity, leading to fluctuations in agricultural exports. Yuhuan and Thann [19] evidenced that climate variables have different impacts, indicating rainfall and CO_2 negatively affected agriculture in Myanmar, whereas temperature impacted agriculture favourably.

Regarding the export supply chain, climate-related disruptions such as extreme weather events (e.g., cyclones, floods) can impact the entire value chain [41]. These events can damage infrastructure, delay transportation, and increase costs, reducing the competitiveness of exports. Moreover, global climate patterns can influence international market prices and demand for agricultural products [42]. Myanmar's export performance is subject to these global dynamics, which can amplify the effects of local climate variability.

We also considered the role of GDP and agricultural production for the export sector in Myanmar. As robust export performance also fuels GDP growth by generating income and employment, a higher GDP can stabilise export performance [43]. As GDP rises, domestic consumption and export capacity can increase, influencing total export dynamics [44]. It also enhances the agricultural sector's resilience through increased investment in infrastructure, technology, and adaptation measures [37]. Improved agricultural productivity through better farming practices and technology adoption can mitigate the adverse effects of climate variability. Efficient production by allocating water, fertilisers, and labour resources can enhance crop resilience to climate stressors, stabilising agricultural output and exports. In developing countries, agricultural exports represent a significant portion of total exports [7]. In Myanmar, agricultural exports have a one-third share of total export revenue, highlighting the sector's importance to the national economy. The share of agricultural exports in total exports can be highly volatile, influenced by factors such as climate conditions, global commodity prices, and trade policies [45]. Fluctuations in agricultural production and global demand can lead to significant variations in the export value and its share in total exports. Hence, this study hypothesises that climate variability has a significant asymmetric impact on Myanmar's agricultural and total exports. Following this hypothesis, we employ a nonlinear econometric model (NARDL), which can capture the asymmetric effects of climate variability.

DATA AND METHODOLOGY

Data and sources

This study collected data from relevant sources, covering an annual time series in Myanmar from 1990 to 2021. To determine the impacts of climate variability on agricultural exports and total exports in Myanmar, we collected the total export value (current US$) and gross domestic product (current US$) from the World Development Indicators [46]. Agricultural gross production value (constant 2014–2016 thousand USD) from the Food and Agricultural Organization [47]. The agricultural export value index was gathered from the Department of Planning, Ministry of Agriculture, Livestock, and Irrigation, Myanmar, statically briefs and glance yearbooks from 1990 to 2021. The climate variables-annual mean temperature (degrees Celsius) and annual rainfall (mm)-were gathered from the World Bank climate change knowledge portal [11], while carbon dioxide (kilotons) was collected from the [48].

Econometric model

This study uses nonlinear autoregressive distributed lag (NARDL) to achieve the study's objective. The ARDL presented by Pesaran et al. [49] did not account for nonlinearity and asymmetrical relationships among variables. Shin et al. [50] created the NARDL, using both positive and negative partial sum decompositions of the explanatory variables to combine long- and short-run nonlinearities. It is an OLS function that uses bounds testing to make long-term inferences. Before the NARDL model's development, cointegration analysis commonly employed vector autoregressive (VAR) and vector error correction model (VECM). Later, Pesaran et al. [49] apply these conditions when the fundamental variables cointegrate at first different levels – I (1) in ARDL and assume symmetric behaviour. Likewise, NARDL can determine the cointegration at I (1) with asymmetric behaviour. We found that previous nonlinear models, such as the threshold error correction model (ECM) by Blake et al. [51] and the Markov-Switching ECM by Psaradakis et al. [52], need to be expanded. Therefore, we apply NARDL to capture the asymmetric behaviours of climate variables. In the study, we consider two response variables (agri-export and total export) to climate variability, so the two models are formulated.

For model (1), studying the asymmetric effects of climate variability on agricultural export in Myanmar, we considered three climate variables and two controlled variables. These controlled variables, agricultural production and GDP, were chosen for their significant influence on agricultural exports. Agricultural export is directly linked to agricultural production, making it a crucial control variable. Similarly, the country's economic growth encourages agricultural investment, boosting productivity and export capacity, making GDP another important controlled variable. Thus, we formulated the following model 1:

$$lnAEX_t = f(lnTEM_t, lnRF_t, lnCO2_t, lnLAGR_t, lnGDP_t) \quad (1)$$

For model 2, studying the asymmetric effects of climate variability on total export in Myanmar, we considered agricultural export and GDP as controlled variables along with the same climate variables. As a least developed country, Myanmar intensely relies on agricultural products such as pulses, rice, wheat, and other agri-products for export. Agricultural exports account for one-third of total exports in Myanmar. Hence, model 2 is formulated as follows:

$$lnTEX_t = f(lnTEM_t, lnRF_t, lnCO2_t, lnLAEX_t, lnGDP_t) \quad (2)$$

lnAEX and *lnTEX* are the natural logs of agri-export and total export, respectively. *lnTEM, lnRF*, and *lnCO*2 are the natural logs of temperature, rainfall, and carbon emission, respectively. *lnAGR* and *lnGDP* represent the natural logs of agricultural gross production value and gross domestic products.

Before delving into a detailed explanation of the NARDL model, we underline the significance of the long-term asymmetry correlations, a key aspect of our research, as follows:

$$lnAEX_t = \beta_0 + \beta_1^+ lnTEM_t^+ + \beta_2^- lnTEM_t^- + \beta_3^+ lnRF_t^+ + \beta_4^- lnRF_t^- + \beta_5^+ lnCO2_t^+ + \beta_6^- lnCO2_t^- + \beta_7 lnAGR_t + \beta_8 lnGDP_t + \varepsilon_t \quad (3)$$

$$lnTEX_t = \alpha_0 + \alpha_1^+ lnTEM_t^+ + \alpha_2^- lnTEM_t^- + \alpha_3^+ lnRF_t^+ + \alpha_4^- lnRF_t^- + \alpha_5^+ lnCO2_t^+ + \alpha_6^- lnCO2_t^- + \alpha_7 lnAEX_t + \alpha_8 lnGDP_t + \varepsilon_t \quad (4)$$

$lnAEX_t$ and $lnTEX_t$ are k×1 vectors of *lnAEX* at time t, β (β_0, β_1^+, β_2^-, β_3^+, β_4^-, β_5^+, β_6^-, β_7, β_8) and *lnTEX* at time t, α (α_0, α_1^+, α_2^-, α_3^+, α_4^-, α_5^+, α_6^-, α_7, α_8) are the asymmetry of long-term behaviours. Climate variables (*lnTEM, lnRF* and *lnCO*2) can be divided as k×1 vector of regressors as follows:

$$lnTEM_t = lnTEM_0 + lnTEM_t^+ + lnTEM_t^- \quad (5.a)$$

$$lnRF_t = lnRF_0 + lnRF_t^+ + lnRF_t^- \quad (5.b)$$

$$lnCO2_t = lnCO2_0 + lnCO2_t^+ + lnCO2_t^- \quad (5.c)$$

$lnTEM_t^+$, $lnTEM_t^-$, $lnRF_t^+$, $lnRF_t^-$, $lnCO2_t^+$, $lnCO2_t^-$ are the partial sum decompositions of positive and negative changes in $lnTEM_t$, $lnRF_t$, and $lnCO2_t$

respectively. The following equations display partial separation of *lnTEM*, *lnRF* and *lnCO*2.

$$lnTEM_t^+ = \Sigma_{i=1}^t \Delta lnTEM_i^+ = \Sigma_{i=1}^t \max(\Delta lnTEM_i, 0) \quad (6.a)$$

$$lnTEM_t^- = \Sigma_{i=1}^t \Delta lnTEM_i^- = \Sigma_{i=1}^t \min(\Delta lnTEM_i, 0) \quad (6.b)$$

$$lnRF_t^+ = \Sigma_{i=1}^t \Delta lnRF_i^+ = \Sigma_{i=1}^t \max(\Delta lnRF_i, 0) \quad (6.c)$$

$$lnRF_t^- = \Sigma_{i=1}^t \Delta lnRF_i^- = \Sigma_{i=1}^t \min(\Delta lnRF_i, 0) \quad (6.d)$$

$$lnCO2_t^+ = \Sigma_{i=1}^t \Delta lnCO2_i^+ = \Sigma_{i=1}^t \max(\Delta lnCO2_i, 0) \quad (6.a)$$

$$lnCO2_t^- = \Sigma_{i=1}^t \Delta lnCO2_i^- = \Sigma_{i=1}^t \min(\Delta lnCO2_i, 0) \quad (6.b)$$

When the model utilises the above concept of cumulative positive and negative partial sums of climate variables, it describes an asymmetrical error-correcting form. The following equations 7 and 8 clearly illustrate:

$$\Delta AEX_t = \beta_0 + \partial lnAEX_{t-1} + \beta_1^+ lnTEM_{t-1}^+ + \beta_2^- lnTEM_{t-1}^- + \beta_3^+ lnRF_{t-1}^+ + \beta_4^- lnRF_{t-1}^- + \beta_5^+ lnCO2_{t-1}^+ + \beta_6^- lnCO2_{t-1}^- + \beta_7 lnAGR_{t-1} + \beta_8 lnGDP_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta lnAEX_{t-i} + \sum_{m=1}^{m=p}(\delta_1^+ \Delta lnTEM_{t-1}^+ + \delta_1^- \Delta lnTEM_{t-1}^-) + \sum_{m=1}^{m=p}(\sigma_1^+ \Delta lnRF_{t-1}^+ + \sigma_1^- \Delta lnRF_{t-1}^-) + \sum_{m=1}^{m=p}(\theta_1^+ \Delta lnCO2_{t-1}^+ + \theta_1^- \Delta lnCO2_{t-1}^-) + \sum_{m=1}^{p} \tau_1 \Delta lnAGR_{t-1} + \sum_{m=1}^{p} \tau_2 \Delta lnGDP_{t-1} + \varphi ECT_{-1} + \varepsilon_t \quad (7)$$

$$\Delta TEX_t = \alpha_0 + \partial lnTEX_{t-1} + \alpha_1^+ lnTEM_{t-1}^+ + \alpha_2^- lnTEM_{t-1}^- + \alpha_3^+ lnRF_{t-1}^+ + \alpha_4^- lnRF_{t-1}^- + \alpha_5^+ lnCO2_{t-1}^+ + \alpha_6^- lnCO2_{t-1}^- + \alpha_7 lnAEX_{t-1} + \alpha_8 lnGDP_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta lnTEX_{t-i} + \sum_{m=1}^{m=p}(\delta_1^+ \Delta lnTEM_{t-1}^+ + \delta_1^- \Delta lnTEM_{t-1}^-) + \sum_{m=1}^{m=p}(\sigma_1^+ \Delta lnRF_{t-1}^+ + \sigma_1^- \Delta lnRF_{t-1}^-) + \sum_{m=1}^{m=p}(\theta_1^+ \Delta lnCO2_{t-1}^+ + \theta_1^- \Delta lnCO2_{t-1}^-) + \sum_{m=1}^{p} \tau_1 \Delta lnAEX_{t-1} + \sum_{m=1}^{p} \tau_2 \Delta lnGDP_{t-1} + \varphi ECT_{-1} + \varepsilon_t \quad (8)$$

In the above equations, β_i and α_i are the long-run coefficients of *LnAEX* and *LnTEX*, whereas δ_i, σ_i, θ_i and τ_i are the short-run coefficients of variables. The null hypothesis states that there is no asymmetrical long-run relationship, stating $\partial = \beta^+ = \beta^- = 0$. We determine the null hypotheses by calculating the F-statistics and comparing them to the two crucial bounds (lower – I (0) and upper – I (1)). These bounds create a range encompassing all potential regressor classifications as I (0), I (1), or commonly cointegrated. We will accept the null hypothesis if the F-statistics are below the lower bound, indicating I (0). The outcome is considered inconclusive if the F-statistics are within the range of I (0) and I (1). If the F values exceed the I (1), we may reject the null hypothesis, indicating the presence of long-term cointegration. The error correction term, ECT (–1), denotes the rate of long-term balance adjustment after a short-term shock.

This study also employs the dynamic multiplier effects of climate variability. The long-term asymmetric coefficients are computed using the formulas; $L_{mi+} = \beta + \frac{\square}{\rho}$ and $L_{mi-} = \beta - \frac{\square}{\rho}$. When the independent factor changes, the long-run coefficient quantifies the relationship between components. The cumulative dynamic multiplier effect can model both long-term and short-term asymmetrical lines. The following equation calculates the percentage change in climate variability in agri-and total exports (X_t^+ and X_t^- on Y_t).

For the dynamic multiplier effects of climate variability on agricultural export:

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial lnAEX_{t+i}}{\partial lnTEM_t^+}, \quad m_h^- = \sum_{i=0}^{h} \frac{\partial lnAEX_{t+i}}{\partial lnTEM_t^-} \quad (9.a)$$

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial lnAEX_{t+i}}{\partial lnRF_t^+}, \quad m_h^- = \sum_{i=0}^{h} \frac{\partial lnAEX_{t+i}}{\partial lnRF_t^-} \quad (9.b)$$

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial lnAEX_{t+i}}{\partial lnCO2_t^+}, \quad m_h^- = \sum_{i=0}^{h} \frac{\partial lnAEX_{t+i}}{\partial lnCO2_t^-} \quad (9.c)$$

For the dynamic multiplier effects of climate variability on total export:

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial lnTEX_{t+i}}{\partial lnTEM_t^+}, \quad m_h^- = \sum_{i=0}^{h} \frac{\partial lnTEX_{t+i}}{\partial lnTEM_t^-} \quad (10.a)$$

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial lnTEX_{t+i}}{\partial lnRF_t^+}, \quad m_h^- = \sum_{i=0}^{h} \frac{\partial lnTEX_{t+i}}{\partial lnRF_t^-} \quad (10.b)$$

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial lnTEX_{t+i}}{\partial lnCO2_t^+}, \quad m_h^- = \sum_{i=0}^{h} \frac{\partial lnTEX_{t+i}}{\partial lnCO2_t^-} \quad (10.c)$$

where if $h \to \infty$, then $m_h^+ \to L_{mi+}$ and $m_h^- \to L_{mi-}$.

RESULTS AND DISCUSSION

Preliminary tests

For analysis, the first step is to present an overview of the data. For this purpose, table 1 shows the descriptive statistics and the correlation of the natural logs of variables. LnGDP has the highest mean value (23.90), whereas the LnTEM has the lowest mean value (3.17). The variables' standard deviations are lower than their respective mean values, indicating favourable performance across the variables. The skewness reveals that LnTEM has a distribution with extended right tails, indicating positive skewness, whereas the rest have distributions with extended left tails, indicating negative skewness. The kurtosis analysis shows that variables except LnRF have a platykurtic distribution, meaning their kurtosis values

Table 1

DESCRIPTIVE AND CORRELATION STATISTICS							
Variables	**LnTEX**	**LnAEX**	**LnTEM**	**LnRF**	**LnCO2**	**LnGDP**	**LnAGR**
Mean	21.94	3.38	3.17	7.62	11.55	23.90	16.76
Median	22.14	3.58	3.16	7.62	11.70	23.99	16.94
Max	23.61	5.05	3.19	7.76	12.18	25.05	17.24
Min	19.59	1.03	3.14	7.40	10.77	22.63	15.97
SD	1.27	1.27	0.01	0.07	0.39	0.83	0.42
Skew	–0.30	-0.30	0.11	–0.56	–0.49	–0.13	–0.45
Kur	1.67	1.68	2.72	3.79	2.22	1.51	1.72
Correlation							
LnTEX	1						
LnAEX	0.99	1					
LnTEM	0.55	0.55	1				
LnRF	0.02	0.02	–0.10	1			
LnCO2	0.81	0.81	0.46	0.15	1		
LnGDP	0.99	0.99	0.55	–0.01	0.79	1	
LnAGR	0.95	0.95	0.52	0.08	0.88	0.94	1

Note: ***, ** and * means 1%, 5% and 10% significant levels.

are less than three, and their tails are skewed positively. The correlation analysis shows that all regressors were positively related to the response variables at the 1% significant level.

After examining the data description and correlation, we employ ADF and PP unit root tests. In the time series analysis, it is necessary to determine whether variables are stationary at a level, I (0), or at the first-different level, I (1), before performing the estimation.

Table 2 shows that LnTEM and LnRF are stationary at the level, whereas the rest are stationary at the first-level difference in ADF, as confirmed by PP. Additionally, we use the structural unit root test during the break year to verify the results using standard unit root tests (i.e., ADF and PP). Table 2 also confirms that variables (LnTEX, LnAEX, LnTEM, LnRF, LnCO2, and LnGDP) are stationary at the level. LnAGR is stationary at the first different level for 2010.

Table 2

UNIT ROOT ANALYSIS							
Standard unit root test	**LnTEX**	**LnAEX**	**LnTEM**	**LnRF**	**LnCO2**	**LnGDP**	**LnAGR**
ADF Level							
Intercept	–1.92	–1.93	–4.14***	–5.70***	–2.14	–2.52	–2.32
Intercept & Trend	–1.21	–1.20	–6.82***	–5.61***	–2.01	1.41	0.66
ADF 1st Difference							
Intercept	–4.59***	–4.64***			–3.91***	–5.80***	–3.64***
Intercept & Trend	–5.06***	–5.07***			–3.98**	–6.36***	–4.87***
PP Level							
Intercept	–2.65	–2.68	–4.14***	–8.60***	–1.99	–1.30	–2.04
Intercept & Trend	–0.89	–0.87	–10.71***	–8.93***	–1.40	0.39	0.63
PP 1st Difference							
Intercept	–4.49***	–4.49***			–3.23**	–5.76***	–3.70***
Intercept & Trend	–5.80***	–5.81***			–3.65**	–6.39***	–4.88***
Structural break unit root test							
At Level							
T-stat	–4.34*	–4.33*	–5.55***	–6.23***	–6.30***	–4.25*	–4.12
Break year	1999	1999	1997	2011	2003	1998	2003
At 1st Different							
T-stat							–5.43***
Break year							2010

Note: ***, ** and * means 1%, 5% and 10% significant levels.

Table 3

BDS TEST FOR NONLINEARITY							
Dimension	**LnTEX**	**LnAEX**	**LnTEM**	**LnRF**	**LnCO2**	**LnGDP**	**LnAGR**
2	0.19***	0.18***	–0.01	0.002**	0.17***	0.20***	0.20***
3	0.33***	0.22***	–0.04***	0.003***	0.28***	0.33***	0.34***
4	0.42***	0.23***	–0.06***	0.002***	0.36***	0.43***	0.43***
5	0.48***	0.22***	–0.03**	–1.69	0.41***	0.49***	0.49***
6	0.52***	0.21***	–0.02**	–1.88	0.44***	0.54***	0.53***

Note: ***, ** and * means 1%, 5% and 10% significant levels.

As this study intends to use nonlinear ARDL, it is necessary to determine whether nonlinearity exists among the variables. So, we check the BDS test that hypothesises that variables are independently and identically distributed. Table 3 displays that LnTEX, LnAEX, LnCO2, LnGDP, and LnAGR are significant at the 1% level for all dimensions, whereas LnTEM and LnRF are significant at the 1% level for four dimensions and three dimensions. These results reject the hypothesis at the 1% significant level, confirming that the variables are nonlinear.

Choosing the appropriate lag order is crucial for accurate model specification. Too few lags can cause model misspecification and omitted variable bias, while too many can lead to overfitting and inefficient parameter estimates. The correct lag length ensures the statistical significance of the included lags and enhances the model's predictive performance. Therefore, we use the vector autoregressive (VAR) lag selection criteria, including the Akaike information criterion (AIC), Schwarz criterion (SC), final prediction error (FPE), likelihood ratio (LR), and Hannan-Quinn (HQ). In table 4, all criteria indicated that Model 1 should have a lag of three while Model 2 should have a lag of one. Additionally, figure 2 shows the polynomial root graphs for the lag selection of two models, indicating that all spots existed within the circles. The VAR lag selection approach supports the suitable assessment of lag lengths for accurate model specification.

Table 4

VAR LAG ORDER SELECTION						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
Model 1: LnAEX (LnTEMLnRF LnCO2 LnGDPLnAGR)						
0	143.29	NA	3.11	–9.46	–9.18	–9.38
1	307.84	249.65	4.66	–18.33	–16.35	–17.71
2	361.99	59.75	1.90	–19.58	–15.90	–18.43
3	443.93	56.50*	2.49*	–22.75*	–17.37*	–21.07*
Model 2: LnTEX (LnTEMLnRF LnCO2 LnGDPLnAEX)						
0	267.88	NA	1.05	–17.45	–17.17	–17.36
1	406.10	211.94*	1.22*	–24.27*	–22.31*	–23.64*
2	441.52	40.14	1.74	–24.23	–20.59	–23.06

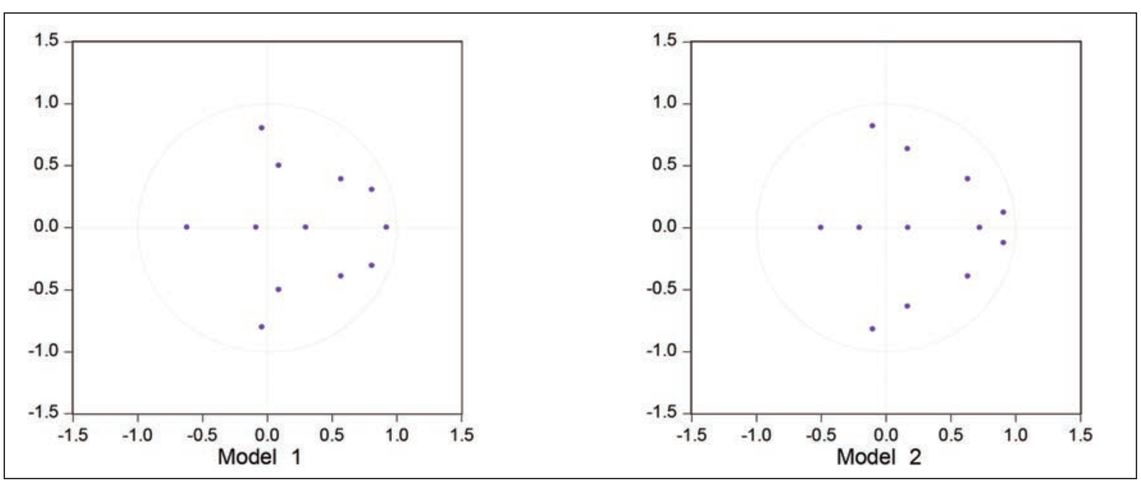

Fig. 2. AR Polynomial root graphs for lag selection

As the nonlinearity and lag selection are confirmed, the Wald test continues to check the long-term asymmetries of the climate variables on agri-export and total exports in Myanmar. The test hypothesises that climate variables have a symmetric relationship with export sectors. Table 5 shows that climate variables LnTEM, LnRF, and LnCO2 have an asymmetric association with agri- and total export at 1% and 5% significant levels, rejecting the null hypothesis. The result suggests that a nonlinear model better represents the relationship between climatic factors and exports in Myanmar.

Table 5

WALD TEST FOR LONG RUN SYMMETRIC RELATIONSHIP			
Variable	**LnAEX**	**LnTEX**	**H0: Long run symmetry ($\partial = \beta^+ = \beta^- = 0$)**
LnTEM	4.91***	3.36**	Rejected
LnRF	–4.10***	–3.41**	Rejected
LnCO2	–3.04***	–3.55**	Rejected

Note: ***, ** and * means 1%, 5% and 10% significant levels.

Once we confirm the asymmetrical relationship, we employ the bounds test for asymmetric cointegration of the variables over the long run. Table 6 shows that the F-statistic values of Model 1 for agricultural exports and Model 2 for total exports are 6.29 and 10.59, respectively, greater than the critical values of the lower and upper bounds at the 1% significant level. The result proves the evidence supporting the long-run correlation between the variables.

NARDL results in the long and short-run

After successfully passing the preliminary tests, we employ the NARDL model. Table 7 presents the model's findings for the impacts of climate variability on agricultural and total exports in Myanmar. Over the long term, increasing temperature (LnTEM+) shows a positive effect, while decreasing one (LnTEM–) indicates a negative impact on both agricultural export (LnAEX) and total export (LnTEX) at a 1% significant level. That is, a 1% increase in both LnTEM+ and LnTEM– leads to an increase in LnAEX by 13.40% and 10.57%, whereas a rise in LnTEX by 1.34% and 0.40%, respectively. Regarding coefficients, the temperature effect on agricultural export is greater than the total export. This result is similar to the previous findings [19,53], showing that temperature has favourable impacts on agriculture and enhanced export quantity. Undeniably, extreme hot and cold temperatures cause severe consequences for agriculture, exports, and a country's economy. However, temperature also has a crucial impact on agricultural productivity, particularly crops. Every crop variety has its temperature requirements for growth and development. In some regions, increasing temperature may benefit agricultural production [37]. Thus, it can be inferred that temperatures can extend the growing season and enhance crop growth, leading to higher yields and more produce available for export in Myanmar.

The increasing rainfall (LnRF+) negatively impacts agricultural export (LnAEX) at a 10% significant level, but decreasing rainfall (LnRF–) is not significant. Decreasing rainfall (LnRF–) negatively affects total export (LnTEX) at a 10% significant level, but increasing rainfall (LnRF+) is not significant. So, a 1% increase in LnRF+ declines in agri-export by 0.78%, while a 1% rise in LnRF– increases total export by 0.01%. As coefficients, the rainfall effect on agri-export is superior to the total export. This finding aligns with prior studies [2, 29], indicating that rainfall adversely affects the countries that rely on agricultural commodities for their economy. As a result, increasing rainfall may lead to heavy rain, which can negatively affect agricultural exports by causing waterlogging, damaging crops, reducing yield, and increasing the risk of crop diseases and pest infestations. In addition, excessive rainfall can disrupt harvest and transportation, leading to delays and quality degradation of export goods. So, decreasing rainfall did not reduce the total export growth in the study. According to Yuhuan and Thann [19], Myanmar faced difficulties with heavy rain, monsoon crop production and reduced yields, which can hinder exports.

Increasing carbon emission (LnCO2+) negatively impacts agri-export (LnAEX) and total export (LnTEX), whereas decreasing carbon emission (LnCO2–) positively affects both of them at 1% and 5% significant levels. It means that a 1% increase in LnCO2+ causes a loss to agri-export by 0.72% and total export by 0.04%, whereas a 1% rise in LnCO2– leads to reduce agri-export by 1.51% and total export

Table 6

BOUND TESTING FOR ASYMMETRIC COINTEGRATION				
Test statistic	**F-stat.**	**Sig.**	**I (0)**	**I (1)**
Model 1 LnAEX (LnTEM, LnRF, LnCO2, LnGDP, LnAGR)	6.29	10%	1.85	2.85
	-	5%	2.11	3.15
	-	1%	2.62	3.77
Model 2 LnTEX (LnTEM, LnRF, LnCO2, LnGDP, LnAEX)	10.59	10%	2.13	3.09
	-	5%	2.38	3.41
	-	1%	2.93	4.06

of about 0.13%. As coefficients, CO_2 affects agri-export more seriously than Myanmar's total exports. These findings are consistent with [2, 54], indicating that rising CO_2 contributes to climate change, which can cause extreme weather events, disrupt growing seasons, and negatively impact agricultural production. Thus, it may further damage the quality and quantity of Myanmar's agricultural and total export volumes. In controlled variables, economic growth (GDP) significantly affects both LnAEX and LnTEX at a 1% level, confirming that economic development strengthens the production of agriculture and export sectors in Myanmar. In the analysis, agricultural production positively impacts agri-export at a 1% significant level. So, this result is aligned with the fact that agriculture is the core sector of Myanmar's exports and economy. This study also finds the link between agri-export and total export. As expected, agri-export positively impacts total exports at a 1% significant level.

Over the short-term, an increasing and decreasing temperature impact in positive and negative manners at 1% and 5% significant levels. That is, a 1% increase in temperature will lead to an 11.39% and 0.58% increase in agri-and total export. In comparison, a 1% decrease in temperature leads to a rise of 3.54% and 0.36% in response variables, respectively. The short-term temperature effects are the same as the long-term temperature effects. Increasing rainfall negatively affects total export, while decreasing rainfall has a positive effect on agri- export at a 1% significant level. So, 1% increased rainfall reduces 0.01% in total exports, while 1% decreased rainfall results in a decline of 1.26% in agri-export. In the short term, decreased rainfall leads to drought or water scarcity, which can affect agri production and further quality and quantity reduction of agri-export in Myanmar. Increasing and decreasing CO_2 affect total exports negatively and positively at 1% significance, whereas their effects on agri-exports are constant. A 1% increase and decrease in CO_2 result in a decline of 0.01% and 0.05% in total exports. CO_2 may cause a reduction in total exports in both runs. In controlled variables, GDP has a 1% significant positive impact

Table 7

NARDL LONG AND SHORT RUN ANALYSIS

	Model 1: LnAEX		**Model 2: LnTEX**	
Long-Run Results	Coef.	t-stat	Coef.	t-stat
LnTEM (+)	13.40***	–1.26	1.34***	7.33
LnTEM (–)	–10.57***	2.16	–0.40**	–5.13
LnRF (+)	–0.78*	2.42	–0.01	–0.95
LnRF (–)	0.47	0.84	–0.01*	–2.87
LnCO2 (+)	–0.72**	–1.92	–0.04***	–5.93
LnCO2 (–)	1.51***	1.07	0.13***	7.34
LnGDP	1.42***	3.09	0.11***	7.41
LnAEX			0.97***	13.3
LnAGR	0.69**	–2.45		
Short Run Results				
DLnTEM (+)	11.39***	7.42	0.58***	17.82
DLnTEM (–)	–3.54**	–2.08	–0.36***	–16.97
DLnRF (+)	C	C	–0.01***	–6.22
DLnRF (–)	1.26***	6.75	C	C
DLnCO2 (+)	C	C	–0.01***	–7.39
DLnCO2(–)	C	C	0.05***	15.00
D(LnGDP)	0.97***	4.05	0.10***	16.57
D(LnAEX)			0.98**	10.41
D(LnAGR)	0.38*	1.84		
ECT (–)	–1.29***	–10.17	–1.59***	–20.58
Diagnosis Tests	**F-stat**	**p-value**	**F-stat**	**p-value**
BG Serial Correlation LM Test:	1.81	0.20	5.04	0.30
Heteroskedasticity Test: BPG	0.78	0.67	1.36	0.45
Heteroskedasticity Test: ARCH	1.26	0.27	2.05	0.13
Jarque-Bera normality test	0.11	0.94	0.09	0.95
Ramsey RESET Test	1.71	0.11	1.45	0.28

Note: ***, ** and * means 1%, 5% and 10% significant levels and C means holding as a constant in the models.

on agri- and total exports, showing a similar effect as long term. Agricultural production indicates a significant positive impact at the 10% level, meaning it plays a vital role in agri-export in Myanmar. When we look at agricultural exports, it has a positive effect on total exports at a 5% significant level. Hence, agri-export is also an essential sector of total exports in Myanmar.

Table 7 also displays several diagnostic tests, including the BG serial correlation LM test, the heteroskedasticity test (BPG and ARCH), the JB normality test, and the Ramsey RESET tests to model solidity. These tests show no apparent association issues with the model. We also apply the CUSUM and CUSUMSQ tests to ensure stable estimations. The calculated coefficients are stable when these test plots remain within the critical boundaries at a 5% significance level. Figure 3 illustrates that the lines did not go beyond the critical boundaries, implying no structural breaks or instabilities in the model. Therefore, the NARDL model successfully passes the stability and reliability tests for estimation.

Robust analysis

Dynamic multiplier effects analysis

Figure 4 exemplifies the results of the dynamic multiplier for the climate variables that impact Myanmar's agricultural and total exports. The dynamic multiplier results show a direct correlation between the multiplier effects of positive and negative temperature, rainfall, and carbon dioxide shocks. These curves depict the rate at which variables change following a one-unit adjustment in exports until they reach long-term equilibrium. Figures 4, *a1* and *b1* highlight the effects of temperature on agri-exports and total exports. An increase in temperature (black line) leads to a rise in agricultural and total exports. A decrease in temperature (black dotted line) also increases agricultural and total exports. In magnitude, temperature affects agricultural exports more significantly than total exports. In the 15th period, an increase and decrease in temperatures reach approximately 10% and 13% on the agri-export, while they only account for 1.4% and 0.4% points on the total export. As a result, increasing or decreasing temperatures positively impact agricultural and total exports. The impact of an increased temperature on agri-exports and total exports outweighs that of a decreased one.

Figures 4, *a2* and *b2* illustrate the effect of rainfall on agri-exports and total exports. An increased rainfall (black line) leads to decreased agri- and total exports. However, a decrease in rainfall (black dotted line) results in a decline in agri-export, but it increases total exports. Regarding impact size, rainfall affects agricultural exports more significantly than total exports. During the last period, the agri-export line decreased by 0.8% and 0.5 % due to increased

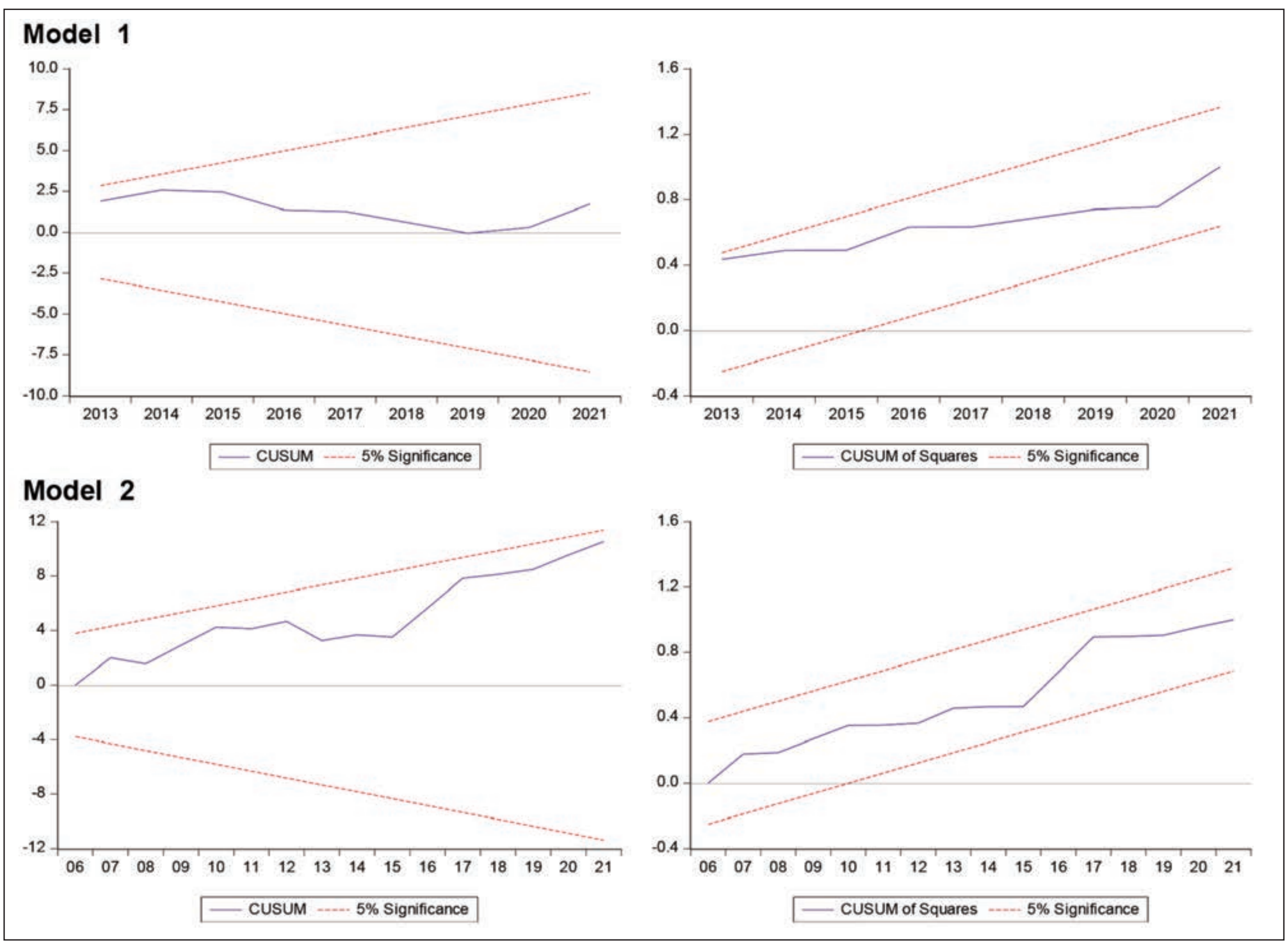

Fig. 3. Stability tests

and decreased rainfall, respectively, while the total export line shows a reduction of around 0.1%. Increased and decreased rainfall harms agriculture exports, whereas decreased rainfall positively impacts total exports. The positive effect of rainfall on Myanmar's agricultural and total export growth outweighs the negative impact.

Figures 4, *a3* and *b3* show the effects of carbon emission (CO_2) on agricultural and total exports. Increased carbon emissions (black line) lead to a drop in agri- and total exports. Decreased carbon emissions (black dotted line) also reduce agricultural and total exports. As a result of the magnitude of CO_2's impact on agricultural exports, it is superior to the total exports. In the last period, increased and decreased CO_2 reached 0.7% and 1.55 in the agri-export line, while they stood at 0.04% and 0.13% in the total export line. Increasing or decreasing CO_2 harms export sectors. Negative CO_2 has a more significant effect than positive ones. Finally, the multiplier effect confirms that climate variability effects on agricultural and total exports align with the long-term results of the NARDL model, as presented in table 8.

FMOLS and DOLS analysis

As the following robust analysis shows, this study utilises the FMOLS and DOLS procedures to verify the results of the NARDL model over a long period. They offer more precise estimates and a comprehensive understanding of the complex connections

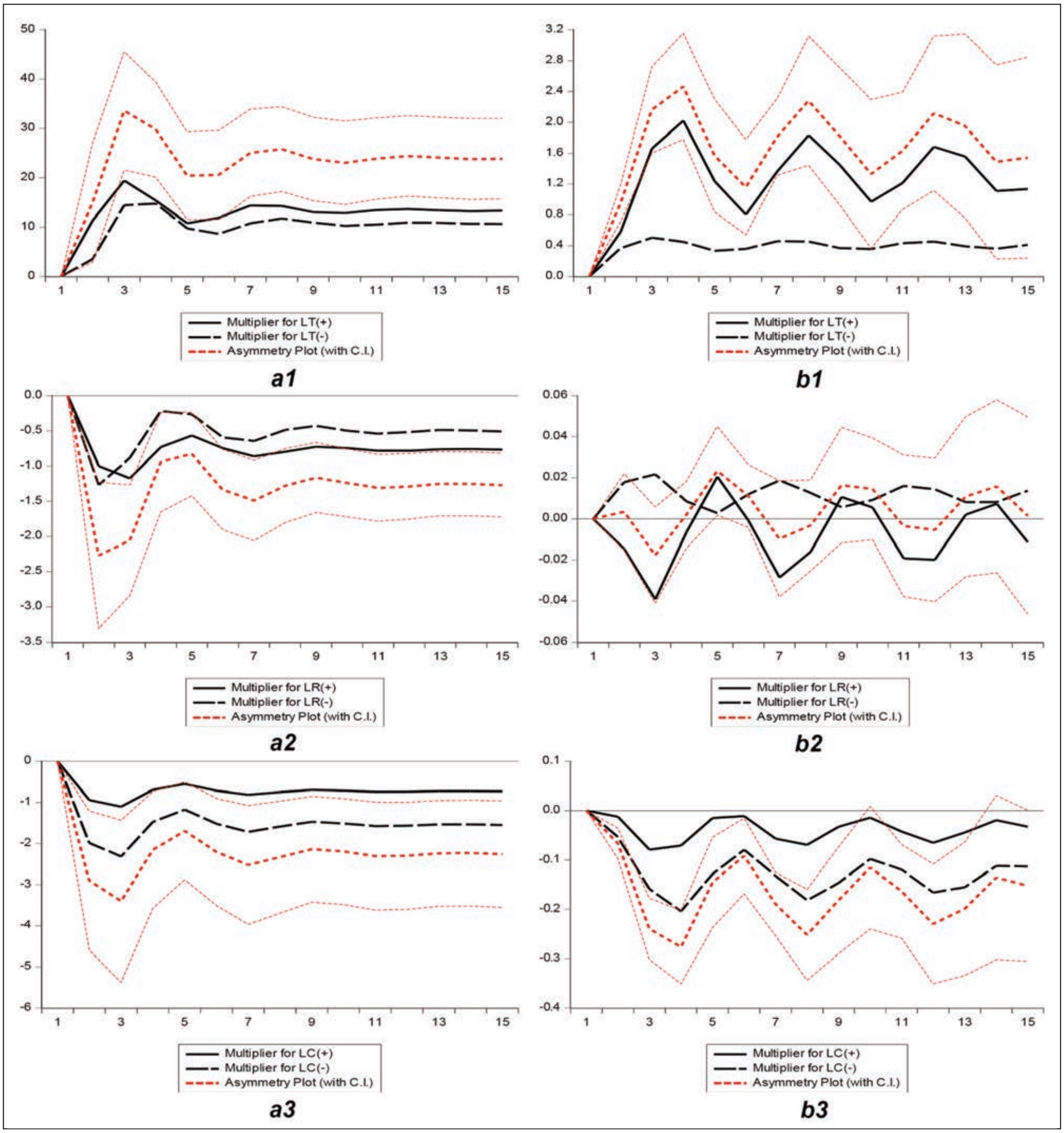

Fig. 4. Dynamic multiplier climate variables effects on agricultural and total exports

Table 8

ROBUSTNESS ANALYSIS								
Variables	Dependent variable: LnAEX				Dependent variable: LnTEX			
	FMOLS		DOLS		FMOLS		DOLS	
	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
LnTEM (+)	10.95***	5.28	11.39***	3.93	0.58***	22.17	0.58***	12.17
LnTEM (–)	–10.11***	–5.40	–10.11***	–3.84	–0.37***	–19.48	–0.36***	–11.40
LnRF (+)	–1.08***	–3.79	–1.01**	–2.54	–0.01**	–5.71	–0.01***	–3.06
LnRF (–)	1.28***	7.18	1.26***	4.92	–0.01***	–11.85	–0.01***	–6.64
LnCO2 (+)	–0.92***	–4.97	–0.93***	–3.50	–0.01**	–7.04	–0.01***	–3.60
LnCO2 (–)	1.94***	5.94	1.95***	4.18	0.05***	13.61	0.05***	7.84
LnGDP	0.96***	3.70	0.97**	2.65	0.10***	18.80	0.10***	10.23
LnAEX	-	-	-	-	0.98***	5.85	0.98***	3.22
LnAGR	1.30***	5.59	1.28***	4.07	-	-	-	-

Note: ***, ** and * means 1%, 5% and 10% significant levels.

among variables [55, 56]. They are unbiased and highly efficient, even amid endogeneity issues. Table 8 explains the estimation results using these two panels. The findings conclusively show that temperature has significant positive impacts on LnAEX (agri-export) and LnTEX (total exports), whereas CO_2 and rainfall have significant negative associations with LnAEX and LnTEX. Therefore, we can infer that the FMOLS and DOLS results resemble the NARDL results, confirming their reliability and validity.

In another train of thought, according to the World Bank report published in November 2023, the garment industry in Myanmar presents a series of particularities, including the significant share of approximately 85% of garment workers who are women, mostly young migrants from poor and rural areas of Myanmar. Moreover, 84% of companies in the garment sector have a positive perception, considering themselves competitive in the main markets [57–59]. Women are also an essential pillar of Myanmar's garment industry, holding the majority of positions as workers, managers (around 56%) or owners. Almost half of Myanmar's garment industry exports are destined for European Union markets, but a significant share is destined for US markets. The garment manufacturers in Myanmar are rather vulnerable and exposed to certain risk factors, including power supply issues, logistic enforcements, currency risk, and difficulties in obtaining licenses for certain production inputs.

Some researchers [60] have studied the natural outputs based on textile dyeing plants, aim to preserve traditional crafts passed down from generation to generation in Chin ethnic communities from Myanmar, but among the most important plant dye species used in the traditional textile industry are the following: "Chromolaenaodorata", "Lithocarpusfenestratus", "L. pachyphyllus". In this sense, agriculture is strongly connected to the traditional textile industry in Myanmar. Traditional textile dyeing is a very authentic traditional craft of Myanmar that contributes significantly to economic growth through the significant contribution of traditional export products.

CONCLUSION AND POLICY IMPLICATIONS

The study investigates the asymmetric impact of climate variability on Myanmar's agricultural and total exports using the NARDL approach for the 1990–2021 annual data. We apply the standard and structural break unit root test to determine the stationary nature of the variables. The results indicate that all variables exhibit mixed stationary behaviour at I (0) and I (1). The BDS test assesses the variables' nonlinearity and shows that they are not independently and identically distributed. The Wald test reveals the presence of asymmetry in the long run between climate variables and agri-and total exports in Myanmar. The diagnosis and stability tests confirm the accuracy and reliability of the model's estimates in the study. The robustness of the NARDL outcome, as confirmed by the dynamic multiplier asymmetry of climate variables and FMOLS and DOLS techniques, provides the reliability of the study.

Over the long and short run, temperatures positively impact agri- and total exports in Myanmar. Increasing temperatures favour export sectors more than decreasing temperatures. In contrast, rainfall negatively affects both agricultural and total exports. Specifically, an increase in rainfall leads to a decline in agricultural exports, while a decrease in rainfall results in an increase in total exports in the long run. Decreasing rainfall declines in agricultural exports, while increasing rainfall reduces total exports in the short run. Increasing rainfall impacts agricultural exports and overall exports more than decreasing ones. Carbon emissions adversely affect agricultural and total exports in both runs. Decreased carbon emissions affect export sectors more than increased ones. In controlled variables, GDP has a positive impact on both agriculture and total exports. Agricultural production contributes significantly to agricultural exports, and agri-exports increase total exports in Myanmar. To summarise, Myanmar's export sectors (agri and total) respond negatively to rainfall and carbon emissions, whereas they respond positively to temperature. The findings also highlight the significant and lasting impacts of climate variables, with the long-term effects proving to be more substantial than the short-term ones. Furthermore, it demonstrates that climate variables have a greater impact on agricultural exports than on total exports, underscoring the seriousness of its implications.

Myanmar's textile and garment industry is export-oriented and very important for the economic growth of this emerging country. Marsh and Lu [61] argued that in the past decade, the European Union fashion industry has had a particular interest in certain sources such as Cambodia and Myanmar, mainly for reasons related to Corporate Social Responsibility concerns. Because the textile and garment industry in Myanmar presents an increased attractiveness, it is understood that it attracts significant foreign direct investments, which contribute to sustainable development and increase the number of workers in this economic sector.

Based on the findings, the study suggests four crucial policy implications for Myanmar, each offering potential benefits. First, investing in irrigation infrastructure, efficient water management techniques, and climate-resilient crop varieties is essential to mitigate the adverse effects of unpredictable rainfall.

Implementing carbon reduction policies and promoting sustainable agricultural practices can help manage carbon emissions. Enhancing climate monitoring and forecasting systems and adopting greenhouse agriculture can stabilise agricultural output in response to temperature changes. Second, diversifying the export base and promoting value-added processing of agricultural products can reduce dependency on climate-sensitive exports, potentially leading to a more stable economy. Developing improved transportation, storage, and climate-resilient infrastructure will help withstand extreme weather events, ensuring trade continuity. Third, implementing training programs for farmers on climate-smart practices and conducting public awareness campaigns on the impacts of climate change are essential for building capacity and fostering sustainable development, potentially leading to a more resilient agricultural sector. Fourth, as climate variables have a greater impact on exports in the long run than in the short run, it is necessary to prioritise long-term climate adaptation and mitigation strategies, potentially leading to a more sustainable future. Moreover, the greater impact of climate variables on agricultural exports compared to total exports underscores the critical vulnerability of the agricultural sector. So, prioritising investment in climate-smart agricultural practices, including climate adaptation and mitigation practices, is required to safeguard agricultural productivity. By addressing these policy areas, Myanmar can better manage the negative impacts of rainfall and carbon emissions on its exports while leveraging the positive effects of temperature increases.

While this study offers valuable insights, it is essential to acknowledge its limitations. We considered temperature, rainfall, and carbon emissions to determine the impact of climate variability. However, we could not consider humidity, wind, and solar radiation as climate variables due to data limitations. Moreover, this study did not include extreme climate change events such as floods, droughts, cyclones, earthquakes, etc. Given the likelihood of climate escalation globally, further research across diverse regions and countries using varied climate and production datasets and methods will be necessary and beneficial. Therefore, this study recommends using panel data analysis like the CSARDL model for group regions like ASEAN and Asia to understand the regional climate change on their economies for further research in the future.

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