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Symmetrical and asymmetrical analysis of the effect of the exchange rate on international trade and its financial consequences: analysis of the situation in Libya

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ABSTRACT: Exchange rate plans are the primary focus of all adjustment attempts, as they are designed to enhance a nation's competitiveness in the global market. The hypothesis posits that a devaluation of the currency will have ramifications for the economy, particularly concerning foreign accounts. The hypothesis further posits that a lower exchange rate may stimulate exports and enhance the trade balance. Acknowledging that the anticipated positive outcomes may persist over an extended duration is imperative. This article will methodically examine the interplay between the exchange rate, trade balance, imports, and exports. Our research employs the linear cointegration approach (ARDL) and the non-linear method (NARDL) from 1970 to 2021, with a focus on Libya. The analysis will demonstrate that healthy capital, consumer, and raw material markets are prerequisites for economic growth. Consequently, economic growth necessitates the availability of additional resources. The government must implement a price stabilization program with all relevant stakeholders to achieve the desired trade balance. The substitution of domestic products for imported goods has the potential to improve the nation's trade balance.

Keywords: Trade balance; Imports; Exports; Exchange rate; ARDL; NARDL; Libya.

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1. Introduction

The development of the Libyan economy and management requires strong fundamentals in terms of the balance of trade, on the one hand, and the transformation of the existing industrial fabric into an ecosystem that creates value and employment, on the other. Rationalizing imports and enhancing exports are crucial to ensuring this development while maintaining competitiveness across multiple sectors.

In most cases, currency devaluation or a change in the parity of a currency by the state only occurs when there is a significant imbalance in the flow of goods and capital. Secondly, this operation is only conceivable under a managed (fixed exchange rate regime) (Gopinath & Itskhoki, 2021). For this reason, devaluation is defined as a change in the value of a national currency in terms of a foreign currency (Krugman, Paul, and Obstfeld, Maurice). We speak of a devaluation when a larger number of national currency units must be given to obtain the same unit of foreign currency. So, there is an increase in the exchange rate. This increase leads to a rise in the price of imported products, which should encourage residents to reduce their consumption of foreign goods. Moreover, the rise in the exchange rate will make domestic products more competitive in terms of price abroad, enabling the country that has devalued its currency to increase its export volumes and gain a market share margin in international trade. So, devaluation has led to an increase in exported products, a decrease in imports, and an increase in demand for the national product.

Libya's financial situation is characterized by abundant liquidity generated by oil revenues, which is mainly reflected in its fiscal and monetary policy and external position. Libya depends on oil revenues as its primary source of income. The oil sector accounts for approximately 94% of foreign currency earnings, 60% of government revenue, and 30% of the country's GDP. According to 2020 statistics, these high percentages render the Libyan economy's performance highly dependent on fluctuations in international oil prices and a decline in production quantities, given that oil is a finite natural resource (Hamida Abourunieh, 2021).

The Libyan economy is characterized by most of the features of developing country economies. It is a monolithic economy relying mainly on oil revenues as the primary source of public expenditure and the most significant contributor to GDP (Mustafa Al-Abdullah Al-Kafri, 2022). Libya's economy is also the least diversified oil economy. Libya's economy is also centrally managed, and the public sector dominates economic activities (Abdullah M'hamed Shamia, 2016).

Our article aligns with the theoretical and empirical literature on the effect of the exchange rate on the balance of trade, imports, and exports in Libya. From this perspective, we seek to answer the following question: *What are the linear and non-linear impacts of the exchange rate on the trade balance, imports, and exports in Libya?*

The remainder of this article is structured as follows: Section 2 of this study proposes a standardised framework for the theoretical and empirical examination of the impact of the exchange rate on the international trade operations of nations such as Libya, including exports, imports, and the trade balance. This methodological framework undergirds our Section 3 study. Section 4 provides a detailed analysis of the Libyan market from 1970 to 2021, exploring the impact of symmetric (ARDL) and asymmetric (NARDL) techniques on the observed results. The estimation results are evaluated and disputed after the discussion in Section 5 and the conclusion in Section 6.

2. Theoretical and empirical literature review

2.1. Theoretical literature review

The relationship between the terms of trade and the external balance of goods and services is dramatically under-explored, theoretically and empirically. Under the Mundell-Fleming model, which is a version of the IS-LM model developed by Hicks (see Hicks, 1937), a country's financial position, as measured by the current account balance, depends on three well-known variables: domestic demand, foreign demand, and the real effective exchange rate, as generally measured by the weighted geometric average of bilateral accurate exchange rates.

External equilibrium is represented by a positive relationship between output and the real exchange rate resulting from trade with the rest of the world. Indeed, to maintain the current account at a sustainable level, any increase in exports initiated by a real depreciation will have to be offset by an equivalent increase in imports over time. Increasing production is necessary to achieve this condition (Bailly et al., 2006).

The relatively more recent theoretical models of hysteresis in world trade show that the high variability of exchange rates and the uncertainty it entails can influence the decision to enter or leave foreign markets in the presence of "sunk" costs (notably Dixit, 1989; Krugman, 1986; Franke, 1991). The notion of "sunk" costs refers to the fixed costs of establishing export production networks, marketing instruments, and distribution infrastructures, and corresponds well to the new realities of modern trade. With such costs, companies tend to react less to short-term fluctuations in exchange rates, displaying a 'wait-and-see' attitude. However, the stronger and longer these fluctuations are, the greater the incentive for companies that have not yet entered international markets to stay away, and for those that have already invested in entering them, to remain. In other words, exchange rates encourage companies to be inert.

From a theoretical perspective, one of the most recent contributions is that of Brollet et al. (2006), who investigated the optimal production decisions of an international firm using portfolio theory. They showed that an increase in exchange rate risk (or an expectation of an increase in exchange rate risk) could have a negative, positive, or neutral impact on trade depending on the elasticity of risk aversion concerning the standard deviation (or mean) of the firm's random profit. These results tend to confirm those of Bacchetta and Van Wincoop (2000).

The impact of exchange rate movements on prices and competitiveness is important when making monetary policy decisions. In this context, it is essential to quantify these effects and to understand the channels through which they operate. This is all the more critical given that the international environment of European economies has undergone numerous changes over the last two decades, with the emergence of the monetary union, advances in European enlargement and integration, as well as the globalization of the production process and the increased exposure of developed economies to international trade. The study presented here emphasizes that the relationships between exchange rates and prices, on the one hand, and competitiveness and growth, on the other, depend primarily on the structural characteristics of the economies and also on the economic shocks at the origin of movements on the currency market (Walque et al., 2019).

The nature of the shocks affecting the economy also plays a crucial role in determining the intensity of the relationship between the exchange rate and consumer prices. An expansive, inflationary monetary policy shock will cause the domestic currency to depreciate, thereby increasing the initial inflationary effect. Prices and the exchange rate, therefore, appear highly correlated. On the other hand, a positive productivity shock lowers the prices of domestic producers, to which the central bank responds by lowering its key rate, resulting in a depreciation. In this case, imported inflation is dominated by the deflationary effect of the initial shock: prices and the exchange rate are then correlated (Ortega et al., 2019).

Because it makes the goods produced by resident firms more competitive with those of their foreign competitors, depreciation is supposed to stimulate a country's economic activity by improving its trade balance. However, the transmission of exchange rate movements to export prices can also be influenced by international trade in intermediate goods. Increased specialization and the underlying development of global value chains may have reduced the substitutability between foreign and domestic goods and services, at least in the short and medium term. These elements weaken the link between price competitiveness and domestic and foreign demand for domestic goods and services, potentially attenuating the fact that devaluation supports economic growth (Walque et al., 2019).

These observations are relevant for monetary policy, which is concerned with price stability and, therefore, reacts to price variations that arise from unexpected movements in the relative value of currencies. However, monetary policy's reaction to inflation also influences exchange rate dynamics through agents' expectations of uncovered interest rate parity. The more aggressively the monetary authorities react to deviations from the inflation target, the greater the impact of exchange rate shocks on final prices.

2.2. Empirical literature review

Although some African countries have experienced growth in recent decades, the continent as a whole remains the poorest in the world, home to some of the least developed countries. It cannot be said that there is a consensus in the economic literature on the positive impact of international trade on economic performance. However, international trade has long been regarded as a valuable engine of economic growth and a reliable means for developing countries to achieve significant economic progress (Edwards, 1993). In developing countries, the impact of trade liberalization depends on several factors; however, the World Bank generally recommends it as a means to eradicate poverty.

This has, however, changed over the last decade as more granular data have become available, leading to a resurgence in work on dominant currencies and their implications for international macroeconomics and finance. In this section, we survey the empirical and theoretical work on dominant currencies, with a focus on the trade channel. Other chapters in this Handbook, including those by Miranda-Agrappino and Rey (2021), Maggiori (2021), Ilzetzki, Reinhart, and Rogo (2021), and Du and Schregger (2021), delve into the financial channel.

The importance of currencies is never more evident than in global trade. Currency exchange rates are often at the center of fierce economic and political debates, including on the architecture of the international monetary system and on the ability of flexible exchange rates to enhance welfare. Today, countries accuse each other of engaging in currency wars and unfair trade competition.

Numerous empirical studies have examined the relationship between international trade and economic growth. Hye et al. (2016) demonstrate that China's long-term and short-term growth are positively correlated with trade openness. Similarly, Ijirshar (2019) conducted a study on the impact of trade openness on economic growth in ECOWAS countries using secondary data from 1975 to 2017. The results indicate that trade openness has a positive long-term effect on the growth of ECOWAS countries, but exhibits mixed effects in the short term.

In 2020, Fatima et al. explored the impact of trade openness on gross domestic product (GDP) growth. They propose considering human capital accumulation (HCA) as an additional dimension of trade integration. The results show an indirect relationship between trade openness and GDP growth. If HCA is considered an intermediate variable, trade can harm GDP growth when countries have a low level of HCA.

On the contrary, Yanikkaya (2003) shows that trade openness has no direct relationship with economic growth; her estimation results show that tariff barriers are positively and, in most specifications, significantly associated with growth, especially for developing countries. Similarly, Huchet-Bourdon et al. (2018) argue that trade openness is a multidimensional concept that cannot be reduced to a single measure, such as the commonly used trade ratios.

Guechari's (2012) research investigates the correlation between Algeria's real effective exchange rate and the trade balance at the global and bilateral level (Algeria's two largest partners: France and the United States) over the period 1981Q1-2009Q4. The main results of this research are as follows: Fluctuations in the real exchange rate had the effect predicted by theory, i.e., a negative price impact in the short term and a positive volume impact in the long term, on the global trade balance as well as on the bilateral trade balance combining the United States and France. The study shows that real exchange rate devaluations have a positive effect on improving the trade balance (Guechari, 2012).

Numerous studies, such as Abreo et al. (2021) and Bakhsh et al. (2022), as well as Álvarez et al. (2018), have highlighted the impact of institutional quality on the trade balance, thereby justifying the inclusion of an institutional variable in the model.

One of the challenges of this editorial project was to solicit contributions based on surveys carried out under unprecedented conditions, whether in terms of field openings or contrasting temporalities. These made it virtually impossible to access fields far from home and have direct contact with respondents and colleagues over long periods. These constraints are linked to travel regulations in many countries, but also undoubtedly to the object itself, trade, which has been little studied by the human and social sciences, and has suddenly been revealed as central to everyday life, as tested by the pandemic crisis. The sudden disappearance of research objects (the case of tourism: Apchain et al., 2021), the reorganization of already advanced data collection (Clouet et al., 2020), the scientific concentration on remote modes of investigation (Bes et al., 2021), but also the sudden appearance of new scientific themes and new "proximity" fields, have marked and oriented the professional daily lives of scientists. While it is not a question of revolutionizing the modes of investigation in all the research carried out during the confinements and during the periods that followed when mobility was regulated, the fact remains that these moments in research are profoundly marked from a methodological and even epistemological point of view.

While the digitization of shopping now seems to have reached a ceiling, thanks to the reopening of retail outlets and the control obtained by elected representatives over the establishment of small urban warehouses dedicated to delivery, the fact remains that the health crisis has encouraged the emergence and long-term establishment of retail infrastructures, driven by international start-ups associated with a racialized underclass (Bernard, 2023). The crisis has served as a reminder that small-scale retailing is a hub of innovation and social resources (Fleury et al., 2020). It is through small-scale retailing that many of the changes taking place in towns and cities can be observed, as well as the socio-spatial inequalities that characterize them. It has also helped to change how retailers are perceived, in terms of revaluing their premises, business practices, professions (Ocejo, 2018), and their significant impact on the urban character of cities (Chabault, 2020). Lastly, the retail approach has enabled the examination of the political challenges facing the sector, particularly in the face of platforms such as Amazon, and the role of retail in the ecological and food transitions (Rollinde, 2022).

Like all research work, it is essential to define hypotheses as a basis for exploration and analysis. In the context of my work, we formulated three fundamental obligations:

H1: The exchange rate positively impacts Libya's trade balance, imports, and exports.

H2: The exchange rate has a symmetrical impact on the balance of trade, imports, and exports.

H3: The exchange rate has an asymmetrical impact on the balance of trade, imports, and exports.

3. Methodology

3.1. Model and variables

International economic and financial transactions are many and varied. Current transactions include international goods, services, income flows, and capital and financial transactions. This section will analyze the primary characteristics of the variables that link the exchange rate to several key indicators, including exports, imports, and the trade balance, in Libya over the study period from 1970 to 2021. The theoretical diagram of the model is as follows in Eq.1:

$$LnBalance_t / LnImports_t / LnExports_t = LnExchange_t + \varepsilon_t \quad (1)$$

The relationship between the terms of trade and the external balance of goods and services is dramatically underexplored, theoretically and empirically. Because of this, the study examined the empirical foundations of the impact of the real exchange rate on global trade balances first and then proceeded to 'rethink' the impact of the terms of trade on the global trade balance, supported by new conceptual developments. We summarize all the variables in Table 1, which are sourced from World Bank databases.

Table 1. Model variables

Variable	Symbol	Nature	Definition
Trade Balance	Balance	Dependent	The trade balance is the difference between the value of goods exported by a country (or economic zone) and those imported by the same country (or zone). The trade balance can be positive if the value of exports exceeds that of imports; the country or region is said to have a trade surplus. It is negative when the value of imports exceeds that of exports; the country or region is said to have a trade deficit.
Importation	Imports	Dependent	Imports of goods and services are transactions (purchases, barter, and gifts) whereby non-residents supply goods and services to residents.
Exportation	Exports	Dependent	Exports of goods and services are transactions (sales, barter, and gifts) in which residents provide goods and services to non-residents.
Exchange rates	Exchange	Explanatory	The exchange rate is the value of one currency against another. It is the rate at which one currency can be exchanged for another.

3.2. Econometric modeling

ARDL modeling is most widely used to evaluate panel data environmental analysis variables. It is independent of the order of integration of the different variables. It differs from the Johansen (1991) method, a co-integration model applied to time series data, and is the classic average. It requires all variables to be integrated into the first order.

On the one hand, the ARDL model offers a precise method for addressing long-range relationships by focusing on the logic of a classical relationship, in which both long- and short-range dynamics are jointly evaluated. Furthermore, it enables us to deal with variables that may have different orders of integration, such as I(0) and I(1), not just I(1). The ARDL model cannot insist on this. According to the ARDL method of Pesaran et al. (1999), the various variables are deemed endogenous. Thus, the overall formula of these models consists of (Eq. 2):

$$y_t = \alpha_0 + \alpha_1 t + \sum_{j=1}^{p} \lambda_j y_{t-j} + \sum_{m=0}^{q} \delta_k{}' x_{t-m} + u_t \quad (2)$$

with x_t representing the set of regressors, which are assumed to be uncorrelated with the residual u_t. Often, we find an equivalent specification (Eq. 3):

$$\Delta y_t = \alpha_0 + \alpha_1 t + \varphi y_{t-1} + \beta' x_t + \sum_{j=1}^{p-1} \lambda_j{}^* \Delta y_{t-j} + \sum_{m=0}^{q-1} \delta_m{}^{*\prime} x_{t-m} + u_t \quad (3)$$

By dissociating the equation of y from those of the other elements of x and adding the divisions of the other corresponding matrices, we can write the equation in the form of an Error Correction Model (ECM) (Eq. 4):

$$\Delta y_t = \alpha_0 + \alpha_1 t + \pi_{yy} y_{t-1} + \pi_{yx} x_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta Z_{t-j} + \varepsilon_{y_t} \quad (4)$$

where $\Pi = \begin{pmatrix} \pi_{yy} & \pi_{yx} \\ \pi_{xy} & \Pi_{xx} \end{pmatrix}$ the variance-covariance matrix of $\varepsilon_t = (\varepsilon_{y_t}\ \varepsilon_{x_t}{}')$ and $Z_t = (y_t\ x_t{}')$. If $\varphi = \pi_{yy}$ and $\beta = \pi_{yx.x}$, after redefining the lag polynomial in Z_t to obtain the contemporary value of xxx in the equal part, it leads to the equation of Pesaran et al. (2001) from the ARDL approach (Eq. 5):

$$\Delta y_t = \alpha_0 + \alpha_1 t + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{j=1}^{p-1} \tilde{\psi}_j{}' \Delta Z_{t-j} + \omega' \Delta x_t + \varepsilon_{y_t} \quad (5)$$

where $\pi_{yx.x} = \pi_{yx} - \omega' \Pi_{xx}$ (matrix 1×k1 \times k1×k), $\omega = \Omega_{xx}{}^{-1} \omega_{xy}$, $\Omega = \begin{pmatrix} \omega_{yy} & \omega_{yx} \\ \omega_{xy} & \Omega_{xx} \end{pmatrix}$ the variance-covariance matrix of ε_t and $u_t = \varepsilon_{y_t} - \omega_{yx} \Omega_{xx}{}^{-1} \varepsilon_{x_t}$. Interestingly, the ARDL model was used to ensure that all elements of the relationship between supply and demand could be considered as I(1) according to the requirements of the VECM specifications. More specifically, the following base equation is written for each period t (Eq. 6):

$$\Delta y_t = \alpha_0 + \alpha_1 t + \varphi y_{t-1} + \beta' x_t + \sum_{j=1}^{p-1} \lambda_{ij}{}^* \Delta y_{t-j} + \sum_{i=0}^{q-1} \delta_i{}^{*\prime} x_{t-i} + u_t \quad (6)$$

Pesaran et al. (1999) propose that the residuals u_t are assumed independent across individuals and the regressions of x_t and for each individual *i*, the long-term relationship is given by (Eq. 7):

$$y_t = \theta_0 + \theta_1 t - \frac{\beta_i{}'}{\varphi_i} x_t + v_t \quad (7)$$

First, we briefly discuss the ARDL cointegration method and implement two steps to make it practical for the cointegration process. At this stage, it is necessary to verify whether a genuine long-term relationship exists between these variables. Then, the null hypothesis that there is no integration or long-term relationship between the variables $H_0: \varphi_i = \beta_i = 0$ is tested against the alternative hypothesis $H_1: \varphi_i \neq 0; \beta_i \neq 0$.

The "*Bounds tests*" procedure is based on Fisher's "F" statistic. Given that the system's variables are I(0) or I(1), the statistic used in this process has a non-standard distribution. Therefore, Pesaran et al. (2001, p.300) calculated two critical values at a given significance level. One series assumes all variables are I(0), and the second assumes all Variables are I(1). When the calculated value of the "F" statistic exceeds the critical value, H_0 is rejected.

At the end of the second step, if a long-term relationship is established, the long-term error correction model (ECM) evaluations of the ARDL model can be obtained from the initial short-term equation. The estimation of the ARDL model begins by determining the number of lags to be introduced. Akaike

Information Criteria (AIC) and Schwartz Criteria (SBC) are often used. The general expression formula of the error correction model (ECM) of the initial short-term equation is as follows (Eq. 8):

$$\Delta y_t = \alpha_0 + \alpha_1 t + \delta EC_{t-1} + \sum_{i=1}^{p} \lambda_i \Delta y_{t-i} + \sum_{k=1}^{K} \sum_{j=0}^{q_k} \delta_j \ \Delta x_{ki,t-j} + \zeta_t \quad (8)$$

where δ is the adjustment parameter speed, and EC is the residuals resulting from estimating the cointegration model of the initial short-term equation. Since we use annual estimates, we conduct tests with up to "p" lags on the first difference of each variable's order and use the F-statistic to calculate the joint significance of the lags of the variables in the initial short-term equation.

The long-term condition model can be extracted from the simplified form of the initial short-term solution, which is written as follows (Eq. 9):

$$y_t = \theta_0 + \sum_{k=1}^{K} \theta_k x_{kt} + \mu_t \quad (9)$$

with $\theta_0 = -\alpha_0/\delta_0$ and $\theta_k = -\beta_k/\delta_0$.

The recently proposed nonlinear autoregressive distributed lag (NARDL) model by Shin et al. (2014) is employed to assess the strength of the transmission of inflation and unemployment in both the short and long term. This methodology offers significant advantages over existing modeling techniques, including the error correction model (ECM), threshold ECM, Markov switching ECM, and smooth transition ECM, by simultaneously modeling cointegration dynamics and asymmetries. In addition to its simplicity of estimation, the NARDL model offers greater flexibility by relaxing the assumption that time series must be integrated in the same order, unlike the ECM model, which is restrictive. Furthermore, it allows for precise differentiation between the absence of linear and non-linear cointegration (Katrakilidis & Trachanas, 2012). Additionally, it is more effective for testing cointegration in small samples (Romilly et al., 2001).

It is now widely accepted that the linear ECM developed by Granger (1981), Engle and Granger (1987), and Johansen (1988) can reproduce short-term deviations of first-order integrated variables from their long-term joint equilibrium. The linear ECM can be expressed as follows:

$$\Delta y_t = \mu + \rho_y y_{t-1} + \rho_x x_{t-1} + \sum_{i=1}^{p=1} \alpha_i \ \Delta y_{i-1} + \sum_{i=0}^{q=1} \beta_i \Delta x_{t-1} + \varepsilon_t \quad (10)$$

Where y_t is the endogenous variable, and x_t is the explanatory variable. The symbol indicates the first difference. The model in Eq. 10 can be used to study short- and long-run relationships between variables when these relationships are well-defined, provided they are linear and symmetric. However, the model is poorly specified when nonlinear and/or asymmetric. In this context, Granger and Yoon (2002) introduce the concept of hidden cointegration, which is detected when two time series are not cointegrated in the classical sense. However, their positive and negative sums are cointegrated.

The NARDL model of Shin et al. (2014) enables us to jointly examine inflation's short-run and long-run responses to unemployment and detect hidden cointegration. This methodology uses the decomposition of the exogenous variable x into its positive and negative partial sums, namely x_t^+ and x_t^- of increases and decreases, such that:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} max(\Delta x_j \,, 0) \text{ and } x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} min(\Delta x_j, 0) \quad (11)$$

In consideration of the short- and long-term asymmetries observed in the linear ECM model, as illustrated in Eq. 11, Shin et al. (2014) proposed an extension to this model, resulting in the general NARDL model, which is expressed as follows:

$$\Delta y_t = \mu + \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i y_{t-i} + \sum_{i=0}^{q-1} (\omega_i^+ \Delta \, x_{t-1}^+ + \omega_i^- x_{t-1}^-) + \varepsilon_t \quad (12)$$

The (+) and (-) superscripts in Eq. 12 represent the positive and negative partial sum decompositions as defined above. The symbols p and q denote the respective lag orders of the dependent variable and the exogenous variable in the distributed lag part. In particular, long-term symmetry can be tested using a Wald test for the dependent variable by testing the null hypothesis $\theta^+ = \theta^-$ in Eq. 11. We can then calculate the long-term positive and negative coefficients as follows: $L_{x^+} = -\theta^+/\rho_x$ and $L_{x^-} = -\theta^-/\rho_x$, with short-term adjustments to positive and negative shocks affecting inflation and unemployment captured by the parameters ω_t^+ and ω_t^-, respectively. Short-term symmetry can also be tested using a standard Wald test of the null hypothesis as $\omega_t^+ = \omega_t^-$ pour $i = 0, \ldots, q-1$. Eq. 11 reduces to the traditional (linear) ECM if both null hypotheses of short- and long-term symmetry cannot be rejected. The failure to reject either the long-term or the short-term null hypothesis results in NARDL with short-term asymmetry (Eq. 13) and with long-term asymmetry (Eq. 14), respectively:

$$\Delta y_t = \mu + \rho y_{t-1} + \rho_t x_{t-1} + \sum_{i=1}^{p-1} \alpha_i y_{t-i} + \sum_{i=0}^{q-1} (\omega_i^+ \Delta x_{t-1}^+ + \omega_i^- x_{t-1}^-) + \varepsilon_t \quad (13)$$

$$\Delta y_t = \mu + \rho y_{t-1} + \rho_y^+ x_{t-1}^+ + \rho_y^- x_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i y_{t-i} + \sum_{i=0}^{q-1} \omega_t \Delta x_{t-1} + \varepsilon_t \quad (14)$$

When asymmetry is detected in the NARDL model, whether in the short term, long term, or both, asymmetric responses to positive and negative x are accounted for in the short term, long term, or both. Asymmetric responses to unit positive and negative shocks (i.e., increases and decreases) in y are as follows: positive and negative x shocks (i.e., increases or decreases) in y_t correspond to x^+ and x^-, respectively (Eq. 15):

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^+} \text{ and } \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^-} \text{ with } h = 0,1,2, \ldots \quad (15)$$

where $h \to \infty, m_h^+ \to Lx^+$, and $m_h^- \to Lx^-$ with Lx^+ and Lx^- are the long-term positive and negative asymmetric coefficients, respectively. Based on the estimated multipliers, we can observe the nonlinear dynamic adjustments of both variables from their initial equilibrium to their new equilibrium state over time following a shock affecting the cointegration system. The NARDL model accounts for short-term dynamics through the distributed lag and long-term dynamics through a single common cointegration vector.

4. Empirical results

4.1. Descriptive analysis

First, the main descriptive statistics for the variables in Table 2 are presented. The normality and autocorrelation test Q (p = 2) and its series probabilities were also assessed using Jarque and Bera's (1987) statistics and probabilities. In addition, Ljung and Box's (1978) serial autocorrelation test is examined.

Table 2. Descriptive analysis

Designation	LnExchange	LnBalance	LnImports	LnExports
Mean	-0.575	7.680	8.414	8.887
Median	-1.010	7.186	7.894	8.272
Standard Deviation	0.692	2.024	1.353	1.397
Minimum	-1.259	3.437	5.447	6.278
Maximum	0.368	11.931	11.254	11.870
Skewness	0.357	0.056	0.162	0.430
Kurtosis	1.237	2.395	2.220	2.037
Coefficient of variation	-1.203	0.263	0.160	0.157
Jarque-Bera (JB)	7.836	0.818	1.546	3.61
p-value JB	0.019	0.664	0.461	0.164
Ljung-Box (LB)	99.93	41.252	75.798	74.245
p-value LB	0.000	0.000	0.000	0.000

Correlation (p-value)	LnExchange	LnBalance	LnImports	LnExports
LnExchange	1.000			
Lnbalance	0.777***	1.000		
LnImports	0.878***	0.774***	1.000	
LnExports	0.886***	0.874***	0.963***	1.000
VIF	1.00			

Notes: VIF refers to the Variance Inflation Factor of Marquaridt (1970). *** refers to the significance p < 0.001.

According to Figure 1, the characteristic of the trade balance variable (Lnbalance) is that it has the same upward and downward trends throughout the study period. In general, the overall mean of this variable is 7.680, and the standard deviation is 2.024, making it more heterogeneous (CV = 0.263). Their values range from 3.437 to 11.931, with a high concentration of around 7.186. The distribution of the sample trade balance is strongly skewed to the right (skewness = 0.056>0), and there is also a strong peak (Kurtosis = 2.395). We reject the null hypothesis of normality using the probability of the Jarque-Bera normality test.

Regarding the Import variable (LnImports), as shown in Figure 2, this series exhibits the same oscillating trends throughout the study period. Overall, the global mean of this variable is 8.414, and the standard deviation is 1.353, which reduces its heterogeneity (CV = 0.160). Their values range from 5.447 to 11.254, with a high concentration of around 7.894. The sample distribution of LnImports extends asymmetrically to the right (skewness = 0.162) and has a strong peak state (kurtosis = 2.220). We reject the null hypothesis of normality using the probability of the Jarque-Bera normality test.

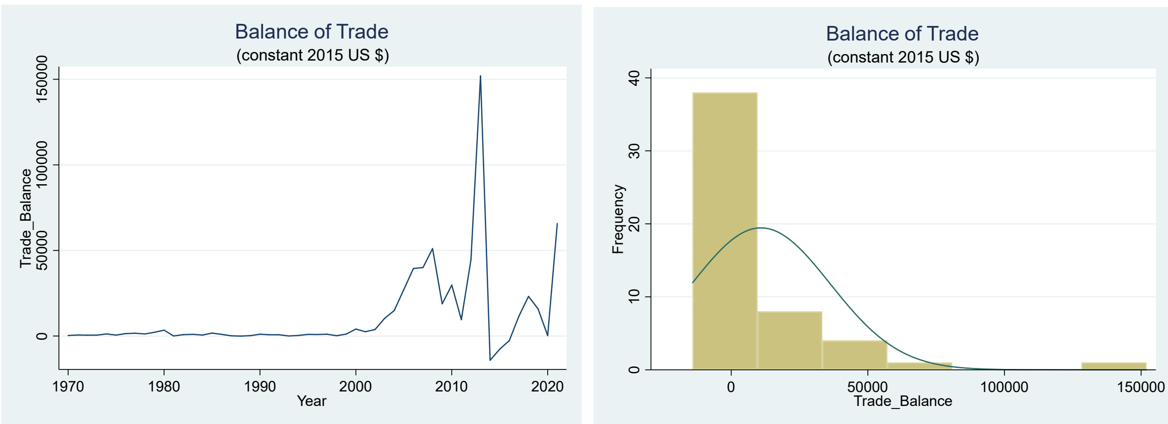

Figure 1. Trend Evolution of Trade Balance

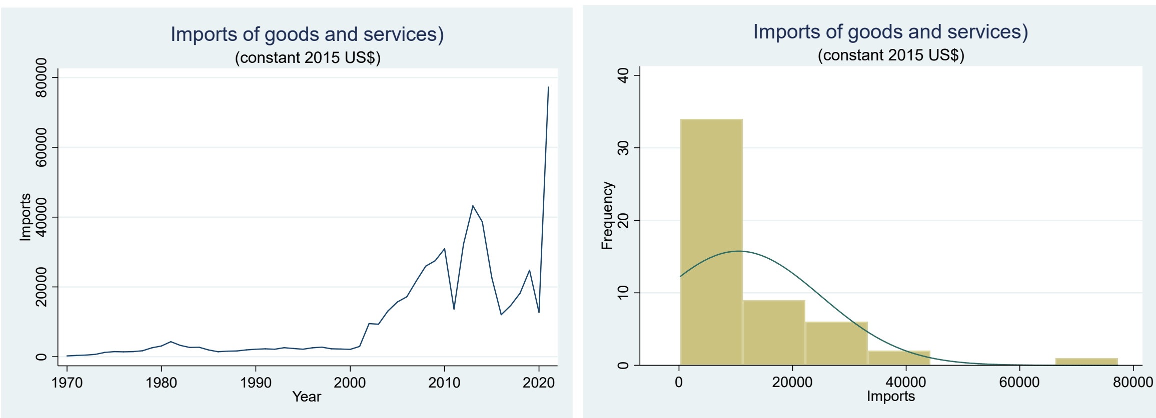

Figure 2. Trend Evolution of Imports

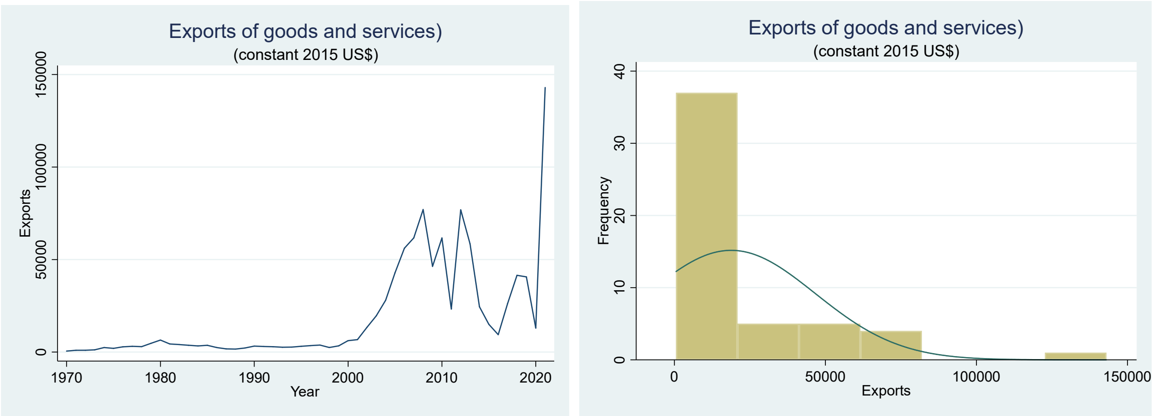

Figure 3. Trend Evolution of Exports

Subsequently, regarding the variable Export (LnExports), as shown in Figure 3, this series exhibits the same oscillating trends throughout the study period. Overall, the global mean of this variable is 8.887, and the standard deviation is 1.397, which reduces its heterogeneity (CV = 0.157). Their values range from 6.278 to 11.870, with a high concentration of around 8.272. The distribution of the LnExports sample extends asymmetrically to the right (skewness = 0.430) and has a strong peak state (kurtosis = 2.037). We reject the null hypothesis of normality using the probability of the Jarque-Bera normality test.

Regarding the last exchange rate variable (LnExchange), as shown in Figure 4, this series exhibits the same oscillating trends throughout the study period. Overall, the global mean of this variable is- -0.575, and the standard deviation is 0.692, which reduces its heterogeneity (CV = -1.203). Their values range from -1.259 to 0.368, with a high concentration of around -1.010. The distribution of the LnExchange sample extends asymmetrically to the right (skewness = 0.357) and has a strong peak state (kurtosis = 1.237). We reject the null hypothesis of normality using the probability of the Jarque-Bera normality test.

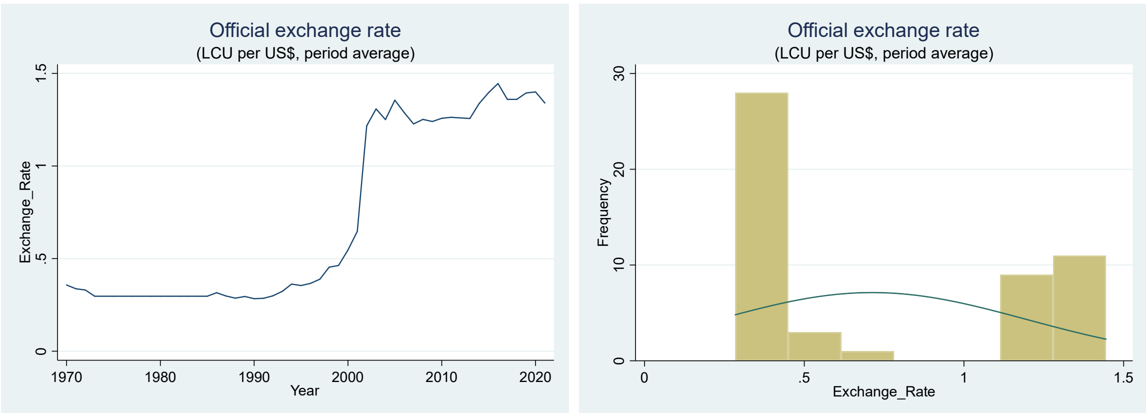

Figure 4. Trend evolution of the Exchange rate

All series generally present autocorrelation problems and the persistence of substantial heterogeneity, which will affect subsequent estimation results.

In the second panel of Table 2, the test of simple correlation coefficients cannot be considered conclusive for the study of exchange rates in relation to the balance of trade, imports, and exports. However, it does give an overall view of the various relationships, which can be detailed below. The simple correlation coefficients detailed in Table 2 show that the exchange rate is positively, significantly, and strongly correlated with the other three variables: Balance, Imports, and Exports. Similarly, the lower part of Table 2 shows that the independent variables are highly correlated. Therefore, the issue of multicollinearity does not arise in our scenario. The Variance Inflation Factor (VIF) measure indicates a value of precisely 1.00, indicating a low value.

4.2. Unit root, dependence, and breakpoint co-integration tests

For purely empirical logic and to determine the order of the sequences used, we correct for the existence of the root unit on the selected variables. This process is critical in convincing the econometric model. Thus, various stationarity tests are used to explain the stationarity of the series. However, some classic tests (such as the Dickey-Fuller (1981) or Phillips-Perron (1988) test) do not take structural changes into account. In this respect, the systematic method of unit root testing with the presence of shocks relies, in particular, on the tests of Zivot and Andrews (1992) and Perron (1997), which consider the null hypothesis of the existence of series unit roots with the presence of structural breaks. We adopt the presence of a single shock, given the small sample size (T = 52).

Table 3. Unit root with break test results

Model	Designation	LnBalance	LnImports	LnExports	LnExchange
		In Level			
A	Break date	2000	2002	2002	2000
	t-statistic	-5.955**	-4.475**	-4.282	-5.254
B	Break date	1989	1995	1992	2013
	t-statistic	-4.859*	-3.136**	-3.076	-2.074
C	Break date	2000	2002	2002	2000
	t-statistic	-5.926	-4.432**	-4.264	-4.097
Decision		NS	NS	NS	NS
Model	Designation	In First Difference			
A	Break date	1990	2001	1999	2004
	t-statistic	-6.883**	-6.807**	-7.695*	-6.566*
B	Break date	2005	1984	1983	2003
	t-statistic	-6.612	-6.718	-7.548**	-6.016
C	Break date	1990	1987	1989	2004
	t-statistic	-6.953	-6.852	-7.713	-6.880**
Decision		S	S	S	S

Note: The critical values at 1% and 5%, respectively, for model A are (-5.34) and (-4.80), for model B (-4.93) and (-4.42), and for model C (-5.57) and (-5.08). *, ** and *** represent significance at 10%, 5% and 1%. NS: non-stationary. S: Stationary.

This section presents the results of the Zivot and Andrews (1992) test for the different transformed series of our two models in level and first difference in Table 3. According to this table, the balance trade variable is non-stationary in level, with significant breaks for the three models: A, B, and C. This break was significant in 1990 for Model A, 2005 for Model B, and 1990 for Model C. However, a study of the stationarity of the same series in the first difference shows that they are all stationary. Therefore, they are considered integrated of order 1 (I[1]). Globally, the majority of variables are not stationary in level, with significant breaks in 1990, 2000, and 2002.

Due to the significance of this issue, it is crucial to identify the presence of multiple breaks using the Ditzen et al. (2021) test. However, we can identify them using the five associated break numbers in Table 4 for the three models, which shows that most variables exhibit significant breaks in 2012 for the trade balance model. For the import model, most variables show significant breaks in 1976, 1985, 1993, 2001, and 2014.

For the export model, most variables show significant breaks in 1976, 2001, and 2013.

Table 4. Unit root with several breaks

Designation		Trade balance model	Import model	Export model
		Test Statistic	Test Statistic	Test Statistic
F(1/0)		6.98	1.78	0.06
F(2/1)		6.28	42.76	18.07
F(3/2)		6.01	14.76	19.98
F(4/3)		5.37	14.77	8.15
F(5/4)		4.97	15.10	9.43
Decision/Number of breaks		1	5	3
		2012	1976/1985/1993/2001/2014	1976/2001/2013

As all the variables are integrated to order 1, we will perform a co-integration test to determine whether they have a long-term relationship. The results presented in Table 5 show that, since the critical values of Gregory and Hansen (1996) are lower than the calculated statistics at the 5% critical threshold, there is at least one long-term co-integration relationship for each variable in our models in the presence of a significant structural break in 1986, 2001, 2002, 2003, 2006. More specifically, at the model level, all ADF* t-statistic values are well above the various critical values, regardless of the model. The reported break year is highly significant, reflecting the crisis years in Libya.

Table 5. Breakthrough co-integration test

Models	Model 2: Level change	Model 3: Level change with trend	Model 4: Change of regime	Model 4: Regime change with trend
ADF Procedure	Trade balance model			
t-statistic *ADF**	-6.61	-6.77	-7.03	-7.32
delay	17	34	34	34
Date of break	1986	2003	2003	2003
ADF Procedure	Import model			
t-statistic *ADF**	-5.15	-5.33	-5.05	-5.38
delay	33	33	37	33
Date of break	2002	2002	2006	2002
ADF Procedure	Export model			
t-statistic *ADF**	-4.57	-5.42	-4.81	-5.67
delay	32	33	32	15
Date of break	2001	2002	2001	1984

Notes: Critical values at 5% significance level: Level change model: ADF* t-statistic (-5.56); Level change model with trend: ADF* t-statistic (-5.83); Regime change model: ADF* t-statistic (-6.41).

The BDS (Brock-Dechert-Scheinkman) test is used to detect nonlinear dependence in time series. Although it was not developed as a leading indicator, the BDS test can help to avoid the false detection of critical transitions due to model misspecification. Rejecting the null hypothesis (i.i.d.) suggests a residual structure in the time series, including hidden nonlinearity, non-stationarity, or an inadequate model fit. As critical transitions are considered to trigger strong non-linear responses, the BDS test is expected to reject the null hypothesis for the residual time series of a system approaching a critical transition. Additionally, the BDS is a two-tailed test, meaning the null hypothesis should be rejected if the BDS test statistic is greater than or less than the critical values (for example, if $\alpha = 0.05$, the critical value = ±1.96).

Table 6. BDS test results

m	LnBalance		LnImports		LnExports		LnExchange	
	p=1	*p=1.5*	*p=1*	*p=1.5*	*p=1*	*p=1.5*	*p=1*	*p=1.5*
2	12.812	8.087	30.010	18.014	23.342	16.874	36.705	29.012
3	13.700	8.457	38.470	19.273	28.245	18.368	44.329	33.358
4	13.639	7.899	50.603	20.953	34.205	19.705	54.949	39.029
5	13.239	7.208	68.473	23.393	42.539	21.570	70.945	47.168
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: p is the multiple of the standard error (or sample size) for the proximity threshold; m is the integration dimension.

Table 6 provides BDS statistics for all variables included in the model. The results strongly suggest that all series (for standard errors p = 1 or p = 1.5 and several inclusion dimensions m = 2, ..., 5) reject the null hypothesis of i.i.d. at a significance level of 1%, implying non-normality and non-linearity of the series by inference.

4.3. Symmetrical model analysis

Table 7 presents the short-term estimates, the recall force of the ECM model, and the set of validity diagnostics for the three models, enabling us to estimate the parameters.

The short-term estimation of the trade balance model, presented as a final ARDL (1,0)-type model, indicates that it is globally significant, given that the probability associated with the final Fisher statistic, equal to 33.95, is less than 5%. It is also of good quality, as the value of the R^2 statistic is low and acceptable, at around 0.6 (0.601). Furthermore, the results of the various model verification tests - respectively, the 10-order Breusch-Godfrey (LM) serial autocorrelation test, the ARCH test for first-order heteroscedasticity, and the Ramsey (RESET) test for functional form validation - confirm that there is no serial autocorrelation, no heteroscedasticity, and the residuals are normally distributed. Specifically, we observe a positive and insignificant effect of the lagged trade balance variable in the short term. From there, we recognize the positive and significant impact of a 5% increase in the exchange rate. We can, therefore, affirm that the balance of trade varies according to price increases in the exchange rate, but to different degrees. The estimated short-term error-correction term (ECM) in the trade balance model (θ) proves the presence of an error-correction mechanism. Thus, the estimated parameter of the ECM term is significant and negative at the 5% significance level. Consequently, a convergence mechanism toward the long-term objective remains in place. To this end, short-term changes in the trade balance will be corrected to a maximum of 0.822%.

The optimal import model is verified by a trendless one-lag ARDL, where the bounds test F-statistic, which displays a value of 8.286 with a significance level of -3.980, is greater than the 5% critical value of Narayan (2005, p. 27), which is equal to 3.872. This leads us to reject the null hypothesis of no cointegration. The short-term estimation of the trade balance model, presented as a final ARDL (1,0)-type model, indicates that it is globally significant, given that the probability associated with the final Fisher statistic, equal to 0.21958, is less than 5%. It is also of good quality, as evidenced by the low and acceptable value of the R^2 statistic, which is around 0.9 (0.907). Furthermore, the results of the various model verification tests - respectively, the 10-order Breusch-Godfrey (LM) serial autocorrelation test, the ARCH first-order heteroscedasticity test, and the Ramsey (RESET) functional form validation test - confirm that there is no serial autocorrelation, no heteroscedasticity, and the residuals are normally distributed. More specifically, we observe a positive and significant effect of the Import lag variable in the short term. From there, we recognize the positive and significant impact of a 5% increase in the exchange rate. We can, therefore, affirm that imports vary according to exchange rate price increases, but to different degrees. The estimated short-term error-correction term (ECM) in the import model (θ) proves the presence of an error-correction mechanism. Thus, the estimated parameter of the ECM term is significant and negative at the 5% significance level. Consequently, a mechanism remains for convergence towards the long-term target. To this end, short-term changes in imports will be corrected to a maximum of 0.430%.

Table 7. Short-term ARDL estimate

ARDL model Δy_t	ARDL (1,0) model Endogenous variable $\Delta LnBalance_t$		ARDL (1,0) model Endogenous variable $\Delta LnImports_t$		ARDL (1,0) model Endogenous variable $\Delta LnExports_t$	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
Constant	7.431	0.000	4.148	0.000	5.259	0.000
$LnBalance_{t-1}$	0.177	0.234	-----	-----	-----	-----
$LnImports_{t-1}$	-----	-----	0.569	0.000	-----	-----
$LnExports_{t-1}$	-----	-----	-----	-----	0.478	0.000
$LnExchange_{t-1}$	1.862	0.000	0.715	0.000	0.908	0.000
θ (ECT)	-0.822	0.000	-0.430	0.000	-0.521	0.000
R^2	0.601	-----	0.907	-----	0.861	-----
Adjusted R^2	0.583	-----	0.902	-----	0.854	-----
F statistic (bounds test)	33.95	-----	219.58	-----	139.35	-----
Durbin–Watson statistics	1.960	-----	2.069	-----	1.866	-----
VIF measure	2.32	-----	3.23	-----	2.93	-----
LM (10) test	0.128	0.720	0.291	0.589	16.944	0.000
McLeod-Li ARCH (p=1) test	0.179	0.672	2.174	0.140	1.275	0.258
White test	2.05	0.872	18.64	0.882	10.71	0.057
Ljung-Box test	7.84	0.449	25.83	0.841	16.04	0.041
Shapiro-Wilk test	0.899	0.000	0.921	0.002	0.931	0.005
Ramsey RESET test	2.31	0.089	1.58	0.210	0.57	0.636

Note: LM test = Lagrange Multiplier test (Breusch-Godfrey serial correlation). ARCH = Autoregressive Conditional Heteroscedasticity Test. RESET is the Ramsey Regression Equation Specification Error test. θ (ECT) is the error correction term that shows the speed of adjustment towards long-run equilibrium (this term must be significantly negative to guarantee the existence of the long-run relationship). k is the number of explanatory variables in the Narayan (2005, p.27) boundary test.

The optimal export model is verified by a trendless one-lag ARDL, where the bounds test F-statistic, with a value of 8.663 and a significance level of 4.110, exceeds the 5% critical value of 3.872, as per Narayan (2005, p. 27). This leads us to reject the null hypothesis of no cointegration. The short-term estimation of the above Export model, presented by a final ARDL (1,0)-type model, shows us that it is globally significant, given that the probability associated with the final Fisher statistic, equal to 139.35, is less than 5%. It is also of good quality, as evidenced by the low and acceptable R^2 statistic value of around 0.8 (0.861). Furthermore, the results of the various model verification tests - respectively, the 10-order Breusch-Godfrey (LM) serial autocorrelation test, the ARCH test for first-order heteroscedasticity, and the Ramsey (RESET) test for functional form validation - confirm that there is no serial autocorrelation, no heteroscedasticity, and the residuals are normally distributed. More specifically, A positive and significant effect of the lagged export variable in the short term is observed. From there, we recognize the positive and significant impact of a 5% increase in the exchange rate. We can, therefore, affirm that exports vary according to exchange rate price increases, but to different degrees. The estimated short-term error-correction term (ECM) in the export model (θ) proves the presence of an error-correction mechanism. Thus, the estimated parameter of the ECM term is significant and negative at the 5% significance level. Consequently, a convergence mechanism towards the long-term target persists. To this end, short-term export changes will be corrected to 0.521%.

In addition, the functional form of the chosen specification is correct. To study the stability of the results, parameter stability tests using the CUSUM method in both mean (CUSUM) and variance (CUSUM squared) indicate that the estimated coefficients remain stable in both mean and variance over the study period and across the three models (see Figure 5).

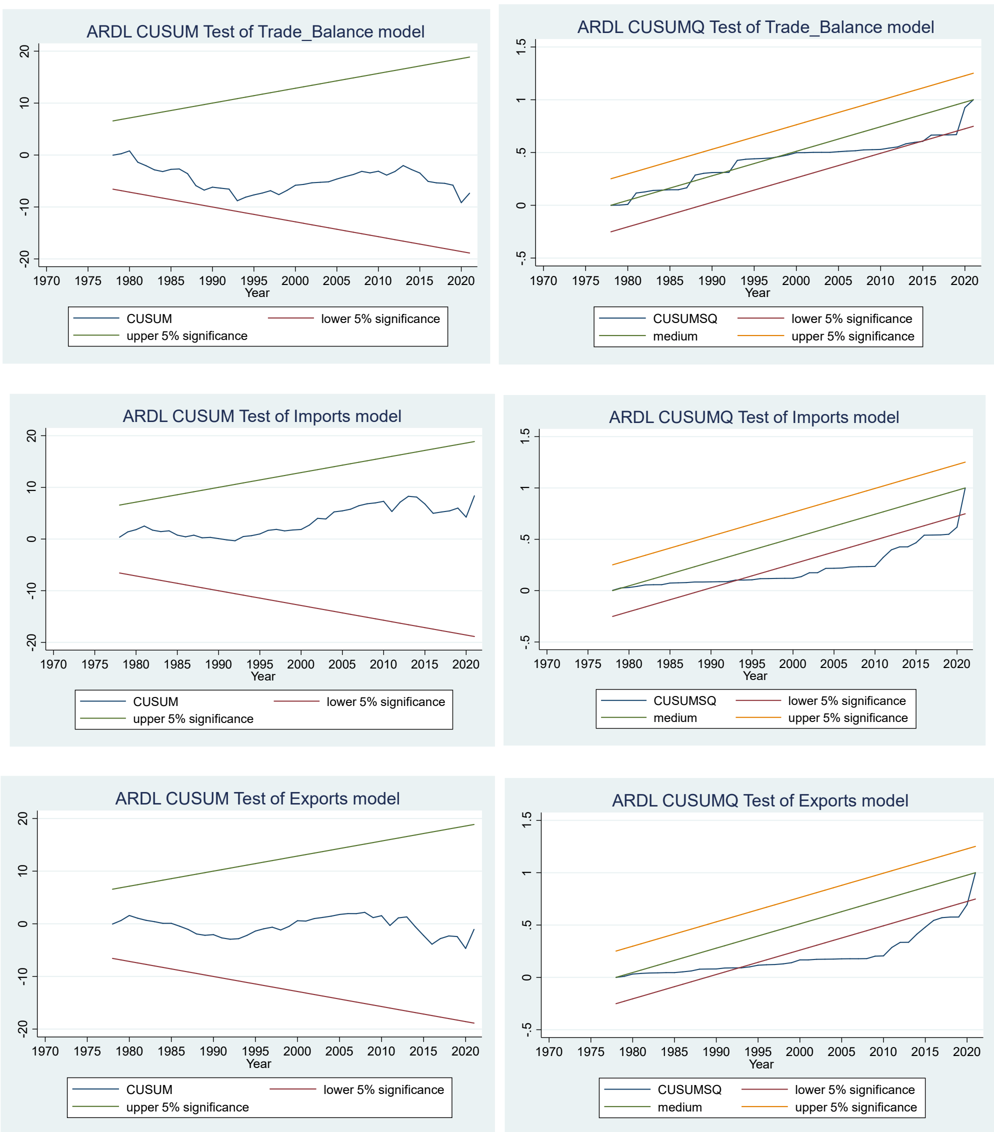

Figure 5. Evolution of CUSUM and CUSUMQ statistics

The long-term relationship estimated by the ARDL approach, as represented in Table 8, indicates that the Exchange variable is positive and significant at a 5% confidence level for all three models.

Table 8. Long-term ARDL estimate

Endogenous variable	Trade balance model		Import model		Export model	
y_t	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
LnExchange	2.263	0.000	1.661	0.000	1.740	0.000

For the trade balance, this will have a positive impact on the exchange rate. Indeed, a 1% increase in the exchange rate will significantly improve Libya's trade balance by 2.263%. Imports will have a positive impact on the exchange rate. Indeed, any 1% increase in the exchange rate will substantially increase Libyan imports by 1.661%. The export variable will have a positive effect on the exchange rate. Indeed, any 1% increase in the exchange rate will generate a substantial increase in exports to Libya of 1.740%.

4.3. Asymmetric model analysis

Based on the above empirical experiments, we have noted that certain relationships, such as the trade balance and the exchange rate, exhibit mixed patterns. For this reason, we have re-estimated our model using an approach that considers asymmetric effects, including that of NARDL.

In what follows, we move on to the non-linear NARDL estimation for the two new variables of LnExchange to find out the relationship between these two variables. First, we tested the asymmetry impact of the exchange rate on the trade balance by subdividing the variable LnExchange into two other variables: $LnExchange^+$ denotes positive variations ($LnExchange^+$ = LnExchange if ΔLnExchange > 0 and 0 otherwise) and $LnExchange^-$ denotes negative variations ($LnExchange^-$ = LnExchange if ΔLnExchange < 0 and 0 otherwise), where Δ represents the first variation. The results of the three models are shown in Table 9.

Table 9. Asymmetry estimation

Variables	LnBalance		LnImports		LnExports	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Constant	6.905	0.000	6.403	0.000	7.292	0.000
$LnExchange^-_t$	3.479	0.210	-4.116	0.001	-1.920	0.142
$LnExchange^+_t$	2.462	0.000	0.803	0.000	1.207	0.000
R^2	0.605		0.854		0.817	
F-Statistic	$F(2, 49) = 37.65^{***}$		$F(2, 49) = 143.96^{***}$		$F(2, 49) = 109.38^{***}$	
Probability F-Statistic	0.000		0.000		0.005	

For the Balance model, the results in Table 9 show a negative and insignificant effect at 5% for the sub-variable LnExchange- and a positive and significant effect at 5% for the sub-variable $LnExchange^+$ on the independent variable Lnbalance. The Fisher test for equality of the two coefficients shows a value equal to F(2; 49) = 37.65 with a probability of 0.000. This leads us to reject the null hypothesis of equality and accept the alternative hypothesis that there is a purely positive asymmetrical effect between the two new variables. We will justify this using the NARDL approach. On the other hand, the results of the Imports model show a negative and significant effect at 5% for the sub-variable $LnExchange^-$ and a positive and significant effect at 5% for the sub-variable $LnExchange^+$ on the independent variable LnImports. The Fisher test for equality of the two coefficients shows a value equal to F(2; 49) = 143.96 with a probability of 0.000. This leads us to reject the null hypothesis of equality and accept the hypothesis that there is an asymmetrical effect between the two new variables, which is mitigated. We will justify this using the NARDL approach. Likewise, the results of the Exports model show a negative and insignificant effect at 5% for the sub-variable $LnExchange^-$ and a positive and significant effect at 5% for the sub-variable $LnExchange^+$ on the independent variable LnExports. The Fisher test for equality of the two coefficients shows a value equal to F(2; 49) = 109.38 with a probability of 0.005. This leads us to reject the null hypothesis of equality and accept the alternative hypothesis that there is a purely positive asymmetrical effect between the two new variables. We will justify this using the NARDL approach.

The short-term estimates of the three models are shown in Table 10. The Balance model is presented by a final NARDL (2; 0; 0) model, which indicates that it is globally significant, given that the probability associated with the final Fisher statistic is less than 5% (F^c equals 2.35). This leads us to reject the null hypothesis of no cointegration. More precisely, the short-term estimates of the NARDL model indicate a positive and non-significant effect at the 5% level of the variable LnExchange, lagged by two periods, on the variation of LnBalance in the short term. This confirms the previous findings on the mixed effect of exchange rate price increases and the trade balance. Generally speaking, in the short term, any increase in the price of the negative or positive exchange rate leads to an increase in the variation of the trade balance. Similarly, the results of the various model verification tests—Breusch-Godfrey's (LM) 5-order serial autocorrelation test, the ARCH test for heteroscedasticity of order 1, Jarque-Bera's (JB) residual normality test, McLeod's test for serial autocorrelation, and Ramsey's (RESET) test for functional form validation—confirm that there is no serial autocorrelation, no heteroscedasticity, and the validity of the model. However, the hypothesis of a normal distribution of residuals was not verified. The estimated short-term error-correction term (ECM) in the trade balance model (θ) of the NARDL model proves the presence of an error-correction mechanism. Thus, the estimated parameter of the ECM term is significant and negative at the 5% significance level. Consequently, a mechanism remains for convergence towards the long-term objective. To this end, short-term changes in the trade balance will be corrected up to 1.240%.

The short-term estimate of the Imports model is presented by a final NARDL (1; 0; 0) model, which indicates that it is globally significant, given that the probability associated with the final Fisher statistic is less than 5% (Fc equals 2.35). This leads us to reject the null hypothesis of no cointegration. More specifically, the short-term estimates of the NARDL model show us a positive and significant effect at 5% of the variable LnImports delayed by one period in the short term. This confirms the previous findings on the mixed effect of exchange rate price increases and imports. Generally speaking, in the short term, any increase in the price of the negative or positive exchange rate leads to an increase in the variation of imports. In addition, the estimated short-term error-correction term (ECM) in the import model (θ) of the NARDL model proves the presence of an error-correction mechanism. Thus, the estimated parameter of the ECM term is significant and negative at the 5% significance level. Consequently, a mechanism remains for convergence towards the long-term target. To this end, short-term changes in the trade balance will be corrected to a maximum of 0.433%.

Table 10. Short-term NARDL estimate

Variables	ΔLnbalance		ΔLnImports		ΔLnExports	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
$LnBalance_{t-1}$	0.273	0.124	-----	-----	-----	-----
$LnExchange^{+}_{t-1}$	-4.025	0.062	-----	-----	-----	-----
$\Delta LnExchange^{+}_{t}$	-3.824	0.106	-----	-----	-----	-----
$LnImports_{t-1}$	-----	-----	3.176	0.000	-----	-----
$LnExports_{t-1}$	-----	-----	-----	-----	4.036	0.000
θ (ECT)	-1.240	0.000	-0.433	0.000	-0.502	0.000
Constant	10.525	0.000	6.403	0.000	7.292	0.000

Finally, the short-term estimate of the Exports model is presented by a final NARDL (1; 0; 0) model, which indicates that it is globally significant, given that the probability associated with the final Fisher statistic is less than 5% (Fc equals 2.35). This leads us to reject the null hypothesis of no cointegration. More specifically, the short-term estimates of the NARDL model show us a positive and significant effect at 5%

of the export variable in the short term. This confirms the previous findings on the mixed effect of exchange rate price increases and exports. Generally speaking, in the short term, any increase in the price of the negative or positive exchange rate leads to an increase in the variation of exports. The estimated short-term error-correction term (ECM) in the export model (θ) of the NARDL model proves the presence of an error-correction mechanism. The estimated parameter of the ECM term is significant and negative at the 5% significance level. Consequently, a mechanism remains for convergence towards the long-term objective. To this end, short-term changes in exports will be corrected to a maximum of 0.502%. Additionally, it is interesting to investigate whether the variables are cointegrated. Otherwise, the coefficients would be spurious when the cointegration relationship is absent.

Table 11. Long-term NARDL estimate

Variables	LnExchange			LnImports			LnExports		
	Coefficient	F-statistic	p-value	Coefficient	F-statistic	p-value	Coefficient	F-statistic	p-value
Long-Term Positive Effect	3.684	77.08	0.000	2.006	5.707	0.022	2.295	15.89	0.000
Long-Term Negative Effect	-10.668	18.71	0.000	12.904	1.425	0.240	13.544	1.469	0.234
Long-Term Asymmetry		11.31	0.002		1.785	0.189		1.975	0.170
Short-Term Asymmetry		2.052	0.161		1.291	0.263		0.086	0.770
Cointegration test	t_BDM	F_PSS		t_BDM	F_PSS		t_BDM	F_PSS	
	-5.697	10.927		-4.931	8.825		-4.392	7.868	
Diagnostic tests	Statistic	Probability		Statistic	Probability		Statistic	Probability	
Jarque-Bera test	24.01	0.000		44.14	0.000		4.493	0.105	
Ramsey test	1.533	0.226		1.458	0.241		1.815	0.166	
Portmanteau test	9.034	0.993		9.879	0.992		12.74	0.940	
Breusch/Pagan heteroskedasticity	1.203	0.272		2.009	0.156		6.074	0.013	

To test for cointegration under an NARDL model, Shin et al. (2014) recommended using the joint null hypothesis of level (undifferentiated) variables and comparing the critical values of the tests linked in Pesaran et al. (2001). If the F calculated is greater than the critical value, there is evidence of cointegration. Otherwise, no evidence of cointegration is found. In the long term, the findings in Table 11 support the previous results, which indicate a strong asymmetry for the three models. Indeed, both the Student (t_BDM) and Fisher (F_PSS) statistics support the existence of a cointegrating relationship, where both values are above the critical values of Pesaran et al. (2001). In addition, the diagnostic tests demonstrate the validity of the model, as the probability of the Ramsey test is greater than 5%, despite the residuals not being normally distributed.

The NARDL (2; 0; 0) Balance model results show a long-term asymmetric effect where the Fisher statistic equals 2.88 with almost zero probability. However, there is no asymmetry in the short term. Similarly, we observe an adverse effect of low long-term $LnExchange^-$, valued at -10.668 with a probability of 0.000, and a positive effect of long-term $LnExchange^+$ valued at 3.684 with a probability of 0.000. Thus, the NARDL model successfully demonstrated a mixed, long-term, asymmetric effect linking the exchange rate and the trade balance in Libya between 1970 and 2021.

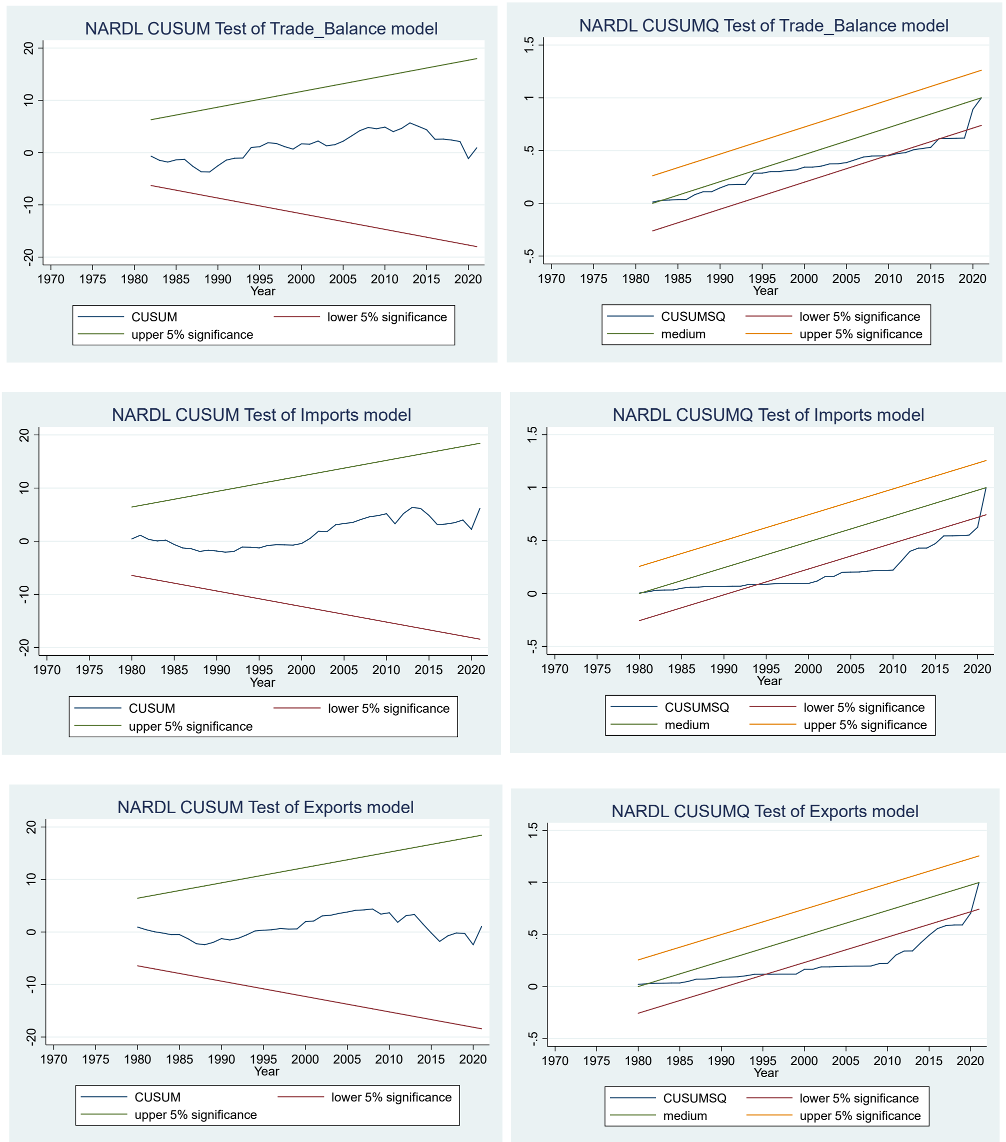

Figure 6. Non-linear evolution of CUSUM and CUSUMQ statistics

The NARDL (1; 0; 0) Imports model results show a long-term asymmetric effect where the Fisher statistic equals 2.49 with almost zero probability. However, there is no asymmetry in the short term. Similarly, we observe an adverse effect of low $LnExchange^-$ in the long term, evaluated at 12.904 with a probability of 0.240, and a positive effect of $LnExchange^+$, evaluated at 2.006 with a probability of 0.000. Thus, the NARDL model successfully demonstrated a mixed, long-term, asymmetric effect linking the exchange rate and imports into Libya between 1970 and 2021.

From the results of the NARDL (1; 0; 0) Exports model, we observe the presence of a long-term asymmetric effect where the Fisher statistic equals 1.68 with almost zero probability. However, there is no asymmetry in the short term. Similarly, we observe a positive long-term effect of low $LnExchange^-$, evaluated at 13.544 with a probability of 0.234, and a positive effect of $LnExchange^+$, evaluated at 2.295 with a probability of 0.000. Thus, the NARDL model successfully demonstrated a mixed, long-term, asymmetric effect linking the exchange rate and exports in Libya between 1970 and 2021. Moreover, the specification functional form chosen is correct, where stability tests on the CUSUM and CUSUM squared parameters prove that the estimated coefficients are stable in mean and variance over the study period (see Figure 6).

In the present study, we aim to demonstrate that Libya faces issues with import and export dysfunction and imperfections. This analytical option leads us to pay particular attention to market policies, which are likely to increase the efficiency of market functioning.

5. Discussion

Libya's economy heavily depends on oil and gas, which account for 97% of exports, over 90% of tax revenues, and 68% of GDP. In 2023, as the country recovered from the 2022 recession, GDP grew by 12.6%, thanks to sustained oil production made possible by the improved security situation. On the demand side, growth continued to be driven by private consumption and exports. Inflation fell to 2.4% in 2023 thanks to improvements in domestic supply chains.

Due to lower global oil prices, the current account surplus decreased to 18.5% of GDP, and the budget surplus declined to 0.1% of GDP. In the absence of a unified state budget for the east and west of the country, salaries, operating expenses, and subsidies continue to be favored to the detriment of public investment. Foreign exchange reserves stood at US$82 billion at the end of 2023 (more than 4 years of import cover). In August 2023, the Central Bank announced reunification with its branch east of the country. The capital adequacy ratio averaged 17.5% over 2019- 2022, above the 12.5% threshold set by the Central Bank. The ratio of non-performing loans to gross loans is high, estimated at 23.1% in the third quarter of 2023.

Peace in Libya remains fragile, with election-related problems still unresolved. The economy is expected to grow by 7.9% in 2024 and 6.2% in 2025, if oil and gas prices and production remain stable. Inflation is expected to remain moderate, at around 2.8% in 2024 and 2.6% in 2025, reflecting the anticipated stability of global food prices. The budget surplus is expected to improve to 4.2% of GDP in 2024 and 8.7% in 2025, while the current account surplus is expected to remain in double digits in 2024 and 2025 due to projected increases in oil and gas exports. Libya's political and security environment is fragile. The country is highly dependent on the oil and gas sector and is vulnerable to the impacts of climate change. Increasing insecurity could lead to an oil blockade, slowing GDP growth. In contrast, a slowdown in global economic growth could hurt international oil prices, reducing Libya's fiscal room for maneuvering.

Different monetary policy frameworks could also affect how central banks implement climate change and net-zero transition measures through monetary policy operations. For example, foreign exchange reserve management is crucial for central banks with pegged exchange rates, so the impact of climate and transition on the strength of these reserves is the first to be considered. Proper reserve management is crucial for controlling exposure to climate-related risks. It would involve reducing exposure while taking advantage of potential growth opportunities during transition (e.g., the measures taken in Singapore for foreign exchange reserve management).

Central banks with a target for their monetary aggregates generally implement their monetary policy through monetary policy operations involving domestic credit. This type of operation is appropriate for targeted refinancing operations aligned with the transition to net zero (see Bingler et al., 2021). Central banks with an inflation target are also affected by climate change and the net-zero transition in specific ways. More specifically, the demand or supply shocks experienced by economies due to climate change and the transition will significantly determine how central banks can respond (McKibbin et al., 2017).

Libya has the financial resources to support a structural reform program. Historically, Libya has had little recourse to external borrowing, thanks to its abundant foreign exchange reserves from oil and gas exports. However, reforming the global financial architecture to increase development loans and make them more affordable could encourage the Libyan authorities to turn to external borrowing. Indeed, substantial financing needs are expected for the country's reconstruction and post-conflict recovery. Structural transformation will require establishing political stability and strong, effective institutions, as well as implementing a comprehensive structural reform program to create an environment conducive to private investment and building modern, sustainable infrastructure.

6. Conclusion and political implications

The trade balance influences exchange rates through its effect on currency supply and demand. When a country's trade account is not net zero, i.e., when exports do not equal imports, there is relatively more supply or demand for its currency. This influences the price of that currency on the world market.

Despite the development plans, policies, and programs implemented over the past four decades, Libya's economy remains monolithic and heavily dependent on oil revenues. Its performance continues to be strongly influenced by fluctuations in world oil prices, on the one hand, and political and security events in Libya since 2011, on the other. In addition, Libya's vast surface area and distinct geographical location qualify it to play a central role in absorbing much of the growth in international trade between Africa and Europe through its ports overlooking the Mediterranean Sea. Not to mention its raw materials and metallic minerals, which, if optimally exploited, could be a source of national income. Libya also has excellent potential as a tourist destination, and if it is utilized to its best advantage, Libya will take its place on the global tourist map.

Due to limited agricultural land and water, the agricultural sector cannot be an alternative strategic sector in diversifying income sources as much as it can be relied upon to reduce the value of imports, cover local needs, achieve self-sufficiency in the main agricultural products, and contribute to job creation. However, despite all these assets and potential, Libya faces numerous challenges that compromise any attempt at development and growth. Historical challenges are inherent to the Libyan economy, including its dependence on oil and command economic policies, which account for a significant share of the public budget and constitute a significant obstacle to the economy's development. Other recent challenges, linked to Libya's political division and current chaos, are obstacles to utilizing Libya's assets and benefiting from high oil prices.

In this respect, public authorities, aware of the existing opportunities, should help Tunisian exporters better position themselves in the Libyan market. It would then be beneficial to reassess economic relations with Libya through partnership initiatives with countries that have successfully established a presence in this market, such as China, Turkey, and certain European Union countries, to enhance cooperation prospects. This is all the more feasible given Tunisia's geographical, linguistic, and cultural proximity to this country, as well as the complementary nature of their trade, which could make our country a platform for strengthening cooperation with this market.

Declaration

This article lacks any research conducted by the authors involving human subjects.

- **Conflicts of Interest:** The authors declare no conflicts of interest.
- **Consent to Participate:** This article contains no studies with human participants conducted by the authors.
- **Clinical trial number**: The Clinical trial is not applicable.
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- **Materials used:** Stata 17 software is used to run various programs.
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