EXCHANGE RATE VOLATILITY AND EXPORT PERFORMANCE IN SMALL OPEN ECONOMIES: IMPLICATIONS FOR MOLDOVA

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Abstract: *Exchange rate volatility is widely recognized as a key determinant of trade performance, particularly in small open economies where external competitiveness is sensitive to currency fluctuations. Despite Moldova's high degree of openness and reliance on external markets, empirical research directly linking exchange rate volatility to its export performance remains limited. This paper synthesizes existing literature on Moldova's exchange rate environment, develops a theoretical and conceptual framework for understanding the volatility–export nexus, and proposes a rigorous methodological approach for future empirical analysis. The paper concludes by identifying critical research gaps and outlining a comprehensive empirical strategy for quantifying the impact of exchange rate volatility on Moldova's exports.*

Keywords: *Republic of Moldova, Real Effective Exchage Rate Volatility, GARCH, ARDL/NARDL, exports, PPML, trade policy.*

Classification JEL: *F10, F13, F14, F17.*

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1. Introduction

Exchange rate dynamics play a key role in shaping the external competitiveness of small open economies. For countries like the case of Moldova – characterized by a narrow export base, high import dependence, and exposure to external shocks – exchange rate volatility can significantly influence trade flows, investment decisions, and macroeconomic stability. While global literature provides extensive evidence on the relationship between exchange rate volatility and trade, Moldova-specific empirical studies remain scarce.

This paper addresses this gap by synthesizing existing research on Moldova's exchange rate environment, developing a theoretical framework for understanding the volatility - export relationship, and proposing a methodological strategy for future empirical work. The paper is structured in the following breakouts: review of the literature; a detailed methodology outline; data description; summary of an empirical results template; and conclusions.

2. Literature Review

The relationship between exchange rate volatility and trade performance has been a subject of extensive research globally. In the context of Moldova, however, the literature remains relatively sparse. This section retrieves the key findings from five relevant sources that, while not directly estimating the impact of exchange rate volatility on exports, provide critical insights into the mechanisms through which exchange rate dynamics influence Moldova's trade and economic performance.

Giucci and Staske (2025) argue that Moldova's historical reliance on the U.S. dollar as a reference currency has contributed to unnecessary exchange rate volatility, particularly given the country's stronger trade ties with the Eurozone. Their policy brief advocates for a shift to the euro as a reference currency to enhance predictability and reduce transaction costs for exporters (Giucci & Staske, 2025).

Gaiu (n.d.) provides a comprehensive analysis of how exchange rate fluctuations affect various economic agents in Moldova, including exporters. The study emphasizes the role of currency risk and its implications for trade decisions, highlighting the need for stable exchange rate policies to support export growth (Gaiu, n.d.).

OGResearch (2023) examines Moldova's real effective exchange rate (REER) and identifies signs of overvaluation, which could undermine export competitiveness. Although the study does not focus on volatility per se, it underscores the importance of maintaining a competitive exchange rate to support external trade.

The IMF (2022) Selected Issues Report includes an in-depth discussion of exchange rate volatility in Moldova, its transmission to inflation, and broader macroeconomic implications. While not centered on exports, its report provides valuable context for understanding how volatility can affect trade indirectly through price stability and investor confidence (IMF, 2022).

Finally, the National Bank of Moldova (2024) introduced new interbank FX market indicators aimed at reducing volatility. These institutional efforts are crucial for creating a stable environment conducive to export growth and foreign investment (National Bank of Moldova, 2024).

Despite these contributions, a notable gap remains in the form of empirical studies that directly quantify the impact of exchange rate volatility on Moldova's export performance. This absence highlights the need for future research that applies econometric models to evaluate the volatility-export nexus in the Moldovan context.

3. Methodology

Most practicians in this field suggest measuring ***Exchange Rate Volatility with GARCH Models*** (GARCH(1,1), EGARCH and TGARCH) as these models help us capture time-varying volatility in the MDL/EUR and MDL/USD exchange rates.

Therefore, we will be starting by using monthly Moldova REER data for the period from the years of 1997 to 2025 (**1997M01–2025M12 (348 observations)**), to compute log returns

$$r_t = \ln(REER_t / REER_{t-1}) \qquad (1)$$

and estimate a **GARCH(1,1)** model by maximum likelihood. The conditional variance follows:

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}, \qquad (2)$$

assuming concomitantly:

$$\varepsilon_t \mid F_{t-1} \sim N(0, h_t) \qquad (3)$$

$$\text{where } \varepsilon_t = r_t - \mu. \qquad (4)$$

Table 1, depicts the estimated parameters that are given by $\mu = 0.00298,\ \omega = 0.000279,\ \alpha = 0.3346,\ and\ \beta = 0.1608$, implying volatility is stationary with $\alpha + \beta = 0.495 < 1$. The time-varying volatility proxy is the conditional standard deviation $\sigma_t = \sqrt{h_t}$, which we annualize for monthly data as $\sigma_t^{ann} = \sqrt{12}\,\sigma_t$. Over the sample, annualized conditional volatility averages **0.0777** (median **0.0686**), with the latest value **0.0644** and a maximum of **0.5446**.

Table 1. GARCH(1,1) estimates for Moldova monthly REER returns (1997M01–2025M12)

Parameter	Description	Estimate
μ	Mean return	0.002980
ω	Constant	0.000279
α	ARCH term	0.334600
β	GARCH term	0.160770
α+β	Persistence (stationarity check)	**0.495370**

Source: *Author's own estimates using monthly Real Effective Exchange Rate (REER) index data for the Republic of Moldova from the National Bank of Moldova. The REER is defined by the NBM as a trade-weighted exchange-rate indicator adjusted for relative inflation, commonly used to assess external price competitiveness. Monthly returns were calculated as log-differences of the REER index, and GARCH(1,1) parameters were estimated by the author for 1997M01–2025M12. Econometric estimations were implemented in R using packages including fixest, AER, urca, and countrycode.*

Notes*: Returns are computed as* $r_t = ln(REER_t/REER_{t-1})$*. The conditional variance is* $h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1}$*, with* $\varepsilon_t = r_t - \mu$*. Estimates obtained by maximum likelihood under conditional normality.* ***Explanations****:* ***Mean return*** *is positive (μ=0.00298), implying an average monthly increase in log REER returns (need to interpret them cautiously; as returns are small). Volatility dynamics show* ***moderate persistence****: α+β=0.495. This suggests shocks to REER volatility decay relatively quickly compared to typical high-persistence FX series; The* ***ARCH component*** *is larger than the GARCH component (α=0.335 vs β=0.161), meaning volatility reacts more to* ***recent shocks*** *than to long memory.*

Now, using the same monthly Moldova REER data for **1997M01–2025M12**, we will compute log returns:

$$r_t = \ln(REER_t/REER_{t-1}), \qquad (5)$$

and estimate an **EGARCH(1,1)** model by maximum likelihood under conditional normality, especially because it can capture asymmetry/ "leverage effects" without forcing variance positivity constraints. Conditional variance is specified as:

$$\ln h_t = \omega + \beta \ln h_{t-1} + \alpha(|z_{t-1}| - E|z|) + \gamma z_{t-1}, \qquad (6)$$

$$\text{where } z_t = \varepsilon_t/\sqrt{h_t}\,, \qquad (7)$$

$$\text{and } E|z| = \sqrt{2/\pi}. \qquad (8)$$

Table 2. EGARCH(1,1) estimates for Moldova monthly REER returns (1997M01–2025M12)

Parameter	Description	Estimate
μ	Mean return	0.003068
ω	Constant (log-variance eq.)	0.000000
α	Magnitude	0.631453
γ	Asymmetry / leverage	0.036928
β	Persistence	0.980000

Sources: *Author's calculations based on monthly Real Effective Exchange Rate (REER) index data for the Republic of Moldova obtained from the National Bank of Moldova. Monthly REER returns were computed as log-differences of the REER index, and the EGARCH(1,1) model was estimated by the author for 1997M01–2025M12.*

Notes: *Returns are* $r_t = ln(REER_t/REER_{t-1})$*. The variance dynamics follow* $ln\, h_t = \omega + \beta\, ln\, h_{t-1} + \alpha(|z_{t-1}| - E|z|) + \gamma z_{t-1}$*, with* $z_t = \varepsilon_t/\sqrt{h_t}$ *and* $E|z| = \sqrt{2/\pi}$*. Estimates obtained by maximum likelihood assuming conditional normality. In the EGARCH specification, α captures the magnitude effect of shocks on conditional volatility, while γ captures possible asymmetric or leverage effects.*

In **Table 2** are presented the estimated parameters $\mu = 0.003068, \omega \approx 0, \alpha = 0.631453, \gamma = 0.036928$, and $\beta = 0.98$, implying highly persistent volatility dynamics (|β|<1). The asymmetry term is positive but small, suggesting only limited evidence that the sign of shocks materially changes volatility relative to shock magnitude. Volatility is measured as $\sigma_t = \sqrt{h_t}$ and annualized for monthly data as $\sigma_t^{ann} = \sqrt{12}\,\sigma_t$.

Continuing using monthly Moldova REER data for **1997M01–2025M12**, we compute log returns $r_t = \ln(REER_t/REER_{t-1})$ similarly as in equation (5) and estimate a **TGARCH (GJR-GARCH)(1,1)** model by maximum likelihood under conditional normality. The conditional variance follows:

$$h_t = \omega + \alpha\varepsilon_{t-1}^2 + \gamma 1(\varepsilon_{t-1} < 0)\varepsilon_{t-1}^2 + \beta h_{t-1}, \qquad (9)$$

$$\text{where } \varepsilon_t = r_t - \mu. \qquad (10)$$

Table 3. shows the estimated parameters μ=0.003274, ω=0.000326, α=0.072772, γ=0.422166, and β=0.089230, with α+0.5γ+β=0.373<1 indicating stationarity. The threshold term is positive (γ>0), implying that negative shocks to REER returns generate higher conditional volatility than positive shocks of the same magnitude. Volatility is measured as $\sigma_t = \sqrt{h_t}$ and annualized for monthly data as $\sigma_t^{ann} = \sqrt{12}\,\sigma_t$.

Table 3. TGARCH (GJR-GARCH)(1,1) estimates for Moldova monthly REER returns (1997M01–2025M12)

Parameter	Description	Estimate
μ	Mean return	0.003274
ω	Constant	0.000326
α	ARCH term	0.072772
γ	Threshold (asymmetry)	0.422166
β	GARCH term	0.089230
α+0.5γ+β	Stationarity check	0.373085
LL	Total log-likelihood	842.6394

Sources: *Author's calculations based on monthly Real Effective Exchange Rate (REER) index data for the Republic of Moldova obtained from the National Bank of Moldova. Monthly REER returns were computed as log-differences of the REER index, and the TGARCH/GJR-GARCH(1,1) model was estimated by the author for 1997M01–2025M12.*

Notes: *Monthly returns are computed as* $r_t = ln(REER_t/REER_{t-1})$ *for the period* ***1997M01–2025M12****. The mean equation is* $r_t = \mu + \varepsilon_t$*, with* $\varepsilon t \mid Ft-1 \sim N(0, ht)$*. The conditional variance follows the TGARCH (GJR-GARCH)(1,1) specification* $h_t = \omega + \alpha\varepsilon_{t-1}^2 + \gamma 1(\varepsilon_{t-1} < 0)\varepsilon_{t-1}^2 + \beta h_{t-1}$ *where* $1(\varepsilon_{t-1} < 0)$ *is an indicator for negative shocks. Parameters are estimated by maximum likelihood assuming conditional normality; stationarity is assessed using α+0.5γ+β<1. A positive γ indicates that negative return shocks increase volatility more than positive shocks of the same magnitude (asymmetric volatility). The dependent variable is the monthly logarithmic return of the REER index. The TGARCH/GJR-GARCH(1,1) model captures volatility persistence and possible threshold/asymmetric effects. The stationarity condition is evaluated using* $\alpha + 0.5\gamma + \beta$*, which equals* ***0.373085****, indicating a stationary conditional variance process.*

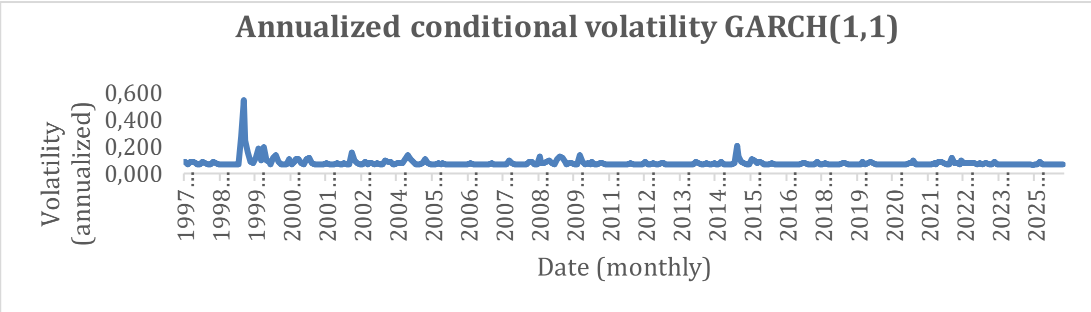

Figure 1. Annualized conditional volatility estimated from a GARCH(1,1) model on monthly REER returns, $\sigma_t^{ann} = \sqrt{12h_t}$.

For an alternative prospective, and by looking at these estimations as a non-parametric benchmark, we compute the rolling volatility as **the standard deviation of exchange-rate log returns over a fixed window**. Let:

$$r_t = \Delta \ln(s_t). \qquad (11)$$

Rolling volatility is defined as

$$\sigma_t^{(w)} = \mathrm{sd}(r_{t-w+1}, \dots, r_t), \qquad (12)$$

with $w = 12$ months, and is annualized as $\sigma_t^{ann} = \sqrt{12}\sigma_t^{(w)}$. (13)

This measure is model-free and provides a transparent comparison to conditional volatility from GARCH-type models.

Simultaneously, in order to capture uncertainty as *unpredictability* rather than realized volatility, we construct an **exchange-rate uncertainty index** from one-step-ahead forecast errors. Using an AR(1) benchmark for returns,

$$r_t = c + \phi r_{t-1} + u_t, \qquad (14)$$

we define uncertainty as:

$$U_t = |FE_t|(or\ FE_t^2), \qquad (15)$$

where $FE_t = r_t - \hat{r}_{t|t-1}$. (16)

The series is aggregated to annual frequency (average within year) and normalized for comparability across measures.

In the next paragraphs, to allow for asymmetric effects on log exports we will use annual exports data of the Republic of Moldova for 1997–2024, to estimate a nonlinear ARDL (NARDL) model in which log REER is decomposed into positive and negative partial sums. As we can observer in **Table 4**, the error-correction term is negative and statistically significant (λ = −2.095, p = 0.008), indicating rapid adjustment toward the long-run equilibrium. Long-run coefficients show a statistically significant effect for the positive REER component (β+ = 1.387, p < 0.001) while the negative component is not significant (β− = 0.050, p = 0.890). Wald tests reject symmetry both in the long run (p = 0.0096) and in the short run (p = 0.0209), supporting asymmetric exchange-rate effects on exports. Standard diagnostics indicate no residual autocorrelation, heteroskedasticity, non-normality, or functional-form misspecification (all p>0.10).

Table 4. NARDL long-run asymmetry results (1997–2024)

Item	**Value**
Bounds F-statistic	4.540
Bounds t-statistic	−3.544
ECM coefficient (λ)$(on(lx_{t-1}))$	−2.095 (**p=0.0076**)
Long-run (β⁺)$(REERpositive)$	1.387 (**p<0.001**)
Long-run (β⁻)$(REERnegative)$	0.050 (p=0.890)
Long-run asymmetry test (Wald)	p=0.0096
Short-run asymmetry test (Wald)	p=0.0209
BG serial correlation	p=0.943
ARCH LM	p=0.915
Normality	p=0.655
RESET	p=0.446

Sources: *Author's own NARDL estimates using annual data for 1997–2024. Export data are taken from the National Bureau of Statistics of the Republic of Moldova; REER data are taken from the National Bank of Moldova; and the foreign-demand proxy is based on World Bank World Development Indicators data. The REER positive and negative partial-sum variables were constructed by the author to test for asymmetric effects.*

Notes: *Positive/negative components are constructed as partial sums of* $\Delta \ln REER_t$. *The dependent variable is* $\ln X_t$. *Case 3 bounds-test critical values (intercept, no trend) are used. The dependent variable is the logarithm of Moldova's exports. The REER variable is decomposed into positive and negative partial sums in order to test whether REER appreciations and depreciations have asymmetric effects on exports. The long-run and short-run asymmetry tests are based on Wald tests. Diagnostic tests report p-values for serial correlation, ARCH effects, normality, and functional-form stability.*

Returning to the conventional definition of the REER (an increase denotes real appreciation), the NARDL estimates indicate that exports respond asymmetrically: real appreciations have a statistically significant long-run effect, whereas real depreciations do not, and symmetry is rejected in both the short and long run. In the linear ARDL, we can see that the long-run REER elasticity is positive but statistically insignificant $\left(\hat{\beta}_{REER} = 0.714, p = 0.33\right)$.

To confirm that by using Moldova's annual export data (1997–2024), we will perform an estimate of a linear ARDL export equation in error-correction form. In **Table 5**, the error-correction (adjustment) coefficient is negative and statistically significant (−0.452, p=0.036), implying that roughly 45% of deviations from the long-run equilibrium are corrected within one year. Long-run multipliers indicate a strong positive association between exports and foreign demand, while the competitiveness effect is weaker: the implied long-run elasticity is 0.714 for REER (p=0.328) and 3.974 for EU GDP (p=0.059). In the short run, changes in foreign demand are positive and significant (Δlfd = 3.381, p=0.0098), whereas short-run REER changes are not statistically significant. Overall model fit is adequate (adjusted R^2 = 0.49).

Table 5. Linear ARDL (UECM) estimates and implied long-run elasticities (annual, 1997-2024)

Panel A. Error-correction form (UECM)

Variable	Estimate	Std. Error	p-value
$L(\ln X, 1)$	−0.4515	0.1985	0.0362
$L(\ln REER, 1)$	0.3224	0.3747	0.4014
L(ln FD,1)	1.7941	1.1701	0.1436
$\Delta L(\ln X, 1)$	0.5282	0.2176	0.0266
$\Delta \ln REER$	0.4365	0.3936	0.2828
$\Delta L(\ln REER, 1)$	−0.4934	0.3468	0.1729
$\Delta \ln FD$	3.3806	1.1630	0.0098
$\Delta L(\ln FD, 1)$	−2.1817	1.1858	0.0833

Sources: *Author's own estimates using annual data for 1997–2024. Export data are taken from the National Bureau of Statistics of the Republic of Moldova; REER data are taken from the National Bank of Moldova; and the foreign-demand variable is proxied by European Union GDP from the World Bank World Development Indicators. Variables are expressed in logarithms, and the ARDL/UECM specification is estimated by the author.*

Notes*: Model fit: R^2=0.6555, adjusted R^2=0.4933; N ≈ 26 (depending on lags). The dependent variable is the logarithm of Moldova's exports. $\ln REER$ denotes the logarithm of the Real Effective Exchange Rate index, while $\ln FD$ denotes the logarithm of the foreign-demand proxy. Panel A reports the unrestricted error-correction form, while the implied long-run elasticities are derived from the estimated level coefficients.*

Panel B. Implied long-run elasticities (multipliers)

Long-run effect	Estimate	Std. Error	p-value
REER	0.7142	0.7095	0.3283
Foreign demand (EU GDP)	3.9737	1.9624	0.0592

Sources: *Author's own estimates using annual data for 1997–2024. Export data are taken from the National Bureau of Statistics of the Republic of Moldova; REER data are taken from the National Bank of Moldova; and foreign demand is proxied by European Union GDP from the World Bank World Development Indicators. The reported long-run multipliers are derived from the estimated ARDL/UECM coefficients.*

Notes*: The long-run elasticities are computed from the level coefficients of the unrestricted error-correction model. The REER elasticity measures the long-run association between Moldova's exports and the real effective exchange rate, while the foreign-demand elasticity measures the long-run association between Moldova's exports and EU GDP used as an external demand proxy.*

In the linear ARDL with specification ARDL(1,0,0) presented in Tables 6 and 7, the bounds test rejects the null of no cointegration (F=7.71, p=0.002), supporting a stable long-run relationship between exports, REER, and foreign demand. Long-run elasticities indicate that foreign demand (EU real GDP) has a strong positive effect on exports ($\hat{\beta}_{FD}$ = 5.09, p=0.0026), whereas the REER elasticity is positive but statistically insignificant ($\hat{\beta}_{REER} = 0.44, p = 0.40$).

Table 6. Linear ARDL long-run elasticities (ARDL(1,0,0), 1997–2024)

Term	Estimate	Std. Error	p-value
lnREER ($\hat{\beta}_{REER}$)	0.4386	0.5164	0.404
lnFD (EU GDP)	5.0888	1.5047	0.0026
Bounds F-test	7.7114		0.0020

Sources: *Author's own estimates using annual data for 1997-2024. Export data are taken from the National Bureau of Statistics of the Republic of Moldova; the REER series is taken from the National Bank of Moldova; and foreign demand is proxied by European Union GDP from the World Bank World Development Indicators. The reported coefficients represent estimated long-run elasticities from the linear ARDL(1,0,0) specification.*

Notes: *The dependent variable is the logarithm of Moldova's exports $\ln X_t$. $\ln REER$ denotes the logarithm of the Real Effective Exchange Rate index, while $\ln FD$ denotes the logarithm of foreign demand, proxied by European Union GDP. The Bounds F-test is used to assess the existence of a long-run relationship among the variables. Bounds test is for the null of no cointegration (case 3).*

Table 7. Linear ARDL(1,0,0) results for total exports, Moldova (1997–2024)

Panel A. Bounds test for cointegration (Pesaran et al.)

Test	Statistic	p-value	Conclusion
Bounds F-test (no cointegration)	7.7114	0.0020	Reject (H_0): cointegration

Panel B. Error-correction model (ECM) estimates

Term	Estimate	Std. Error	p-value
Constant	−70.9477	18.5643	0.000875
$\ln X_{t-1}$	−0.5015	0.1281	0.000696
$(\ln REER_t)$	0.2200	0.2918	0.4586
$(\ln FD_t)(EUGDP)$	2.5522	0.6542	0.000719

Panel C. Implied long-run elasticities

Variable	Long-run elasticity
$(\ln REER)$	0.4386
$(\ln FD)(EUGDP)$	5.0888

Sources: *Author's own estimates using annual data for 1997–2024. Export data are taken from the National Bureau of Statistics of the Republic of Moldova; the REER series is taken from the National Bank of Moldova; and foreign demand is proxied by European Union GDP from the World Bank World Development Indicators. The Bounds test, ECM coefficients, and implied long-run elasticities are derived from the estimated linear ARDL(1,0,0) model.*

Notes: *Dependent variable is $\ln X_t$, where X_t is total exports (USD). FD_t is EU real GDP. Annual sample 1997–2024. Panel A reports the bounds test for the null of no cointegration (case 3: intercept, no trend). Panel C long-run elasticities are computed as $-\theta/\lambda$, where λ is the coefficient on $\ln X_{t-1}$ and θ is the relevant level coefficient in Panel B.*

The NARDL results in Table 8 indicate statistically significant **asymmetry**: long-run effects are concentrated in REER increases (real appreciations), while REER decreases (real depreciations) are not significant; diagnostic tests support model adequacy.

Table 8. NARDL results for total exports and REER asymmetry, Moldova (1997–2024)

Panel A. Cointegration (Bounds) tests

Test	Statistic	Notes
Bounds F-statistic	4.5398	Inconclusive at 10% (above lower bound 4.29, below upper bound 5.08); below 5% lower bound (5.395)
Bounds t-statistic	−3.5440	Significant vs. 10%/5% critical bands; supports cointegration

Panel B. Error-correction (UECM) estimates

Term	Estimate	Std. Error	p-value
Constant	28.3557	8.0735	0.00794
$\ln X_{t-1}$	−2.0946	0.5910	0.00758
$REER^{+}_{t-1}$	2.9044	0.9118	0.01289
$REER^{-}_{t-1}-$	0.1044	0.7415	0.89156

(Short-run differenced terms are included in the estimation; see notes.)

Panel C. Long-run elasticities and asymmetry tests

Item	Value	p-value
Long-run β^{+} (REER increases)	1.3866	<0.001
Long-run β^{-} (REER decreases)	0.0498	0.8899
Long-run asymmetry (Wald)	11.4406	0.0096
Short-run asymmetry (Wald)	8.2173	0.0209

Panel D. Diagnostics

Test	p-value
Breusch–Godfrey serial correlation	0.9431
ARCH LM	0.9154
Normality	0.6554
RESET	0.4463

Sources: *Author's calculations using annual data for 1997–2024. Moldova's total export data are taken from the National Bureau of Statistics of the Republic of Moldova; REER data are taken from the National Bank of Moldova; and foreign demand is proxied by European Union GDP from the World Bank World Development Indicators. The NARDL positive and negative partial-sum decomposition and asymmetry tests follow Shin et al. (2014), while the Bounds-test approach follows Pesaran, Shin and Smith (2001).*

Notes: *Dependent variable is $\ln X_t$ (total exports, USD). $REER^{+}$ and $REER^{-}$ are partial sums of positive and negative changes in $\Delta \ln REER_t$. Cointegration is assessed using case 3 critical values (intercept, no trend). Panel B reports the key level terms of the UECM; the full model includes lagged differences of $\Delta \ln X_t$, $\Delta REER^{+}_{t}$, and $\Delta REER^{-}_{t}$ as in our earlier NARDL output. Annual sample 1997–2024.*

Just as a general signpost in our estimations by far, in the Bruegel CPI-based REER index, increases denote real appreciation; therefore, the NARDL positive partial sum captures appreciations ($\Delta \ln REER_t > 0$) and the negative partial sum captures depreciations ($\Delta \ln REER_t < 0$).

By completing those ARDL/NARDL estimates, we will turn now to analyze Moldova's bilateral export flows for the years 1997–2024 using a gravity framework estimated by **Poisson Pseudo-Maximum Likelihood (PPML)**. PPML is appropriate for trade data because it is robust to heteroskedasticity and accommodates **zero trade flows** while keeping the dependent variable in **levels** (rather than requiring log-transformation). To control for time-invariant partner characteristics and common global shocks, we include **importer fixed effects** and **year fixed effects**, and cluster standard errors by importer to allow for within-partner dependence over time.

The baseline specification in our case is:

$$X_{it} = exp[\beta_1(EU_i \times Post2014_t) + \beta_2(EU_i \times Post2022_t) + \alpha_i + \delta_t]\varepsilon_{it} \quad (17)$$

where $\boldsymbol{X_{it}}$ denotes Moldova's exports to partner i in year t, $\boldsymbol{\alpha_i}$ are importer fixed effects, and $\boldsymbol{\delta_t}$ are year fixed effects. The interaction $\boldsymbol{EU_i \times Post2014_t}$ captures the differential change in exports to EU partners after **2014 (DCFTA period)** relative to non-EU partners, while $\boldsymbol{EU_i \times Post2022_t}$ measures any additional **EU-specific** change after 2022 (note that year fixed effects absorb shocks common to all partners in each year).

The baseline PPML model includes 38 importer fixed effects and 28 year fixed effects and achieves a high adjusted pseudo-$\boldsymbol{R^2}$ (≈0.91), indicating that partner heterogeneity and common time shocks explain a substantial share of the variation in bilateral exports. Fit statistics (log-likelihood and BIC) are reported to benchmark and compare alternative specifications.

In Table **9** we report the PPML estimates' results. The coefficient on **EU × post-2014** is positive and highly significant across specifications, indicating a strong post-2014 increase in exports to EU partners relative to non-EU partners after controlling for importer and year effects. By converting the coefficient to percentage terms, using:

$$\left(e^{\beta} - 1\right) \times 100, \quad (18)$$

the post-2014 EU effect implies an increase of approximately +250 – 263% (DCFTA effect (model 2): $\boldsymbol{e^{1.289} - 1} \approx 263\%$, DCFTA effect (model 3, 2014–2021): $\boldsymbol{e^{1.254} - 1} \approx 250\%$). By contrast, the EU × post-2022 coefficient is small and statistically insignificant ($\boldsymbol{e^{0.0932} - 1} \approx 9.8\%$), suggesting no clear additional EU-specific structural break from 2022 onward, once common year shocks are controlled for.

Table 9. PPML estimates of Moldova's bilateral exports: DCFTA (2014) and 2022 shock

	(1) Baseline	**(2) DCFTA**	**(3) DCFTA + 2022**
EU × post-2014 (eu_post2014)		1.289*** (0.3252)	1.254*** (0.1804)
EU × post-2022 (eu_post2022)			0.0932 (0.6015)
Importer FE (imp_iso3)	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
SE clustered by importer	—	Yes	Yes
Observations	1,064	1,064	1,064
Squared Cor.	0.7890	0.8925	0.8945
Pseudo R^2	0.9111	0.9405	0.9405
BIC	11,718,470.8	7,845,436.6	7,836,126.3

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the provisional application of the EU–Moldova Association Agreement/DCFTA since September 2014, while the EU × post-2022 variable captures the post-2022 external shock period. Importer and year fixed effects are included, with standard errors clustered by importer. PPML estimation follows Santos Silva and Tenreyro (2006), with high-dimensional fixed effects implemented following Correia, Guimarães and Zylkin (2020).*

Notes: *Dependent variable is bilateral exports (levels). Estimation by PPML with importer and year fixed effects. Standard errors clustered by importer (imp_iso3). Significance: *** p<0.001, ** p<0.01, * p<0.05. The percentage effect translation shows the following magnitudes: 1.289 ≈ +263%; 1.254 ≈ +250%; 0.093 ≈ +10% but insignificant*

Overall, the PPML findings align with the time-series results: external demand and policy regime shifts (DCFTA period) are central in explaining export dynamics, while competitiveness effects captured by REER are weaker in the linear model and appear mainly through asymmetry in NARDL.

For more clarity in our above estimates, we will concentrate on interpreting the essence of each number:

- **dcfta_pct = 262.88%.** From the model with only **EU × post-2014**, this means exports to EU partners are estimated to be about **263% higher** after 2014 **relative to non-EU partners**, controlling for importer and year fixed effects.
- **dcfta_2014_2021_pct = 250.40%.** In the model with both interactions, this is the EU post-2014 effect **for 2014–2021** (before the 2022 interaction kicks in): about **250% higher** relative to non-EU.
- **shock_increment_pct = 9.77%.** This is the **additional change from 2022 onward** for EU partners (the coefficient on **EU × post-2022**): about **+9.8%** on top of the post-2014 effect. In our table it was **not statistically significant**, so it could be treated as "no clear EU-specific 2022 shift."
- **dcfta_post2022_total_pct = 284.63%.** This is the **total EU effect after 2022**, combining both coefficients: $e^{\beta_{2014}+\beta_{2022}} - 1$. So, from **2022 onward**, exports to EU partners are estimated to be about **285% higher** relative to non-EU, in that specification.

In **Table 9**, we notice that the coefficient on **EU × post-2014** is **positive and highly significant** (1.254), indicating that Moldova's exports to EU partners increased strongly after the DCFTA period began, relative to non-EU partners, after controlling for importer fixed effects and common year shocks. The **EU × post-2022** coefficient is **small and statistically insignificant** (0.093), suggesting there is no clear additional EU-specific break in exports from 2022 onward once the general 2022–2024 shocks (captured by year fixed effects) are accounted for. The high pseudo-(R^2) (0.94) and squared correlation (0.89) imply the model with fixed effects fits the bilateral export pattern well.

In short, the interpretation of the two-policy model (ppml_both) gives us the following conclusions:

- eu_post2014 = estimated **DCFTA-era shift** in exports to EU relative to non-EU partners (net of importer FE and year FE).

- eu_post2022 = **additional change from 2022 onward** for EU partners (captures "2022 shock" differential).

If **eu_post2022** is negative, it means EU flows fell relative to non-EU after 2022; if positive, they rose.

Across methods, the results point to **external demand and policy regime shifts** as the main drivers of Moldova's export dynamics, while **price-competitiveness effects are weaker and asymmetric**. In the time-series ARDL/NARDL models, EU GDP has a strong positive effect on exports, whereas the REER effect is generally weak in the linear specification but becomes asymmetric in NARDL (with appreciations and depreciations behaving differently). Consistent with this, the PPML gravity estimates show a large, robust increase in bilateral exports to EU partners after **2014 (DCFTA)**, while the additional **2022 shock** term is not EU-specific once common year shocks are controlled for, suggesting the post-2014 policy anchor matters more than a differential partner-group break in 2022.

Simultaneously, to assess whether the DCFTA-related shift in exports to EU partners depends on Moldova's macro-financial environment, we will estimate a Hansen-style panel threshold model, proxied by annual exchange-rate volatility. Formally, we estimate:

$$y_{it} = \beta_L(EU_i \times Post2014_t)1(vol\_ann_t \leq \hat{\gamma})$$

$$+\beta_H(EU_i \times Post2014_t)1(vol\_ann_t > \hat{\gamma}) + \alpha_i + \delta_t + \varepsilon_{it}, \quad (19)$$

where: $$y_{it} = log(1 + exports_{it}) \quad (20)$$

while α_i and δ_t denote importer and year fixed effects. The threshold γ is selected by grid search over trimmed candidate values (10%–90%) to minimize the residual sum of squares, and standard errors are clustered by importer. In **Table 10** the estimated volatility threshold is $\hat{\gamma} = 116.366$, which splits the sample into low- and high-volatility regimes.

Table 10. Hansen-type panel threshold results (threshold variable: annual volatility)

Item	Result
Threshold variable q_t	Annual volatility (vol_ann)
Estimated threshold $\hat{\gamma}$	116.366
Dependent variable	$y_{it} = \log(1 + \text{exports}_{it})$
Fixed effects	Importer FE + Year FE
SE	Clustered by importer

Sources: *Author's own estimates using Moldova's bilateral export data from the National Bureau of Statistics of the Republic of Moldova and monthly REER data from the National Bank of Moldova. The threshold variable, annual volatility* (vol_ann)*, is constructed from monthly REER returns. The panel threshold specification follows Hansen's threshold-regression approach and is estimated with importer and year fixed effects, with standard errors clustered by importer.*

Note: *The dependent variable is* $y_{it} = log(1 + exports_{it})$*, where iii denotes importer partner and ttt denotes year. The estimated threshold* $\gamma = 116.366$ *separates observations into low- and high-volatility regimes. The threshold variable qtq_tqt is the annual REER volatility series constructed by the author.*

The post-2014 EU (DCFTA) effect shown in **Table 11** is positive and statistically significant in both regimes, but substantially larger under high volatility: the coefficient equals 1.345 (p=0.048) in the low-volatility regime and 2.184 (p=0.003) in the high-volatility regime. A formal difference test rejects equality of the regime coefficients (high–low = 0.838, p=0.0013), confirming a statistically meaningful threshold effect. These results suggest that

Moldova's post-2014 export reorientation toward EU partners is robust and appears even stronger during periods of elevated volatility.

Table 11. Regime-specific DCFTA effect (EU × post-2014):

Coefficient	Estimate	Std. Error	p-value
$EU \times Post2014\ (lowvol, vol_ann \leq \hat{\gamma})$	1.345	0.652	0.048
$EU \times Post2014\ (highvol, vol_ann > \hat{\gamma})$	2.184	0.673	0.003

Sources: *Author's calculations based on Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova and monthly Real Effective Exchange Rate (REER) data from the National Bank of Moldova. Annual REER volatility* (vol_ann) *was constructed by the author from monthly REER returns. The EU × post-2014 variable is constructed to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from 1 September 2014. Regime-specific coefficients are estimated using the Hansen-type panel threshold model with importer and year fixed effects.*

Note: *The table reports the estimated DCFTA effect separately for low-volatility and high-volatility regimes, where the regime split is determined by the estimated annual volatility threshold* $\hat{\gamma} = 116.366$. *Standard errors are clustered by importer. A larger coefficient in the high-volatility regime suggests that the DCFTA effect is stronger when REER volatility exceeds the estimated threshold.* ***Difference test:*** *High − Low = 0.838 (SE 0.235), t = 3.56, p = 0.0013.*

This threshold result complements the PPML gravity findings of a strong post-2014 DCFTA shift toward EU markets by showing that the EU effect is **not only robust on average**, but **significantly larger when exchange-rate volatility is high** (the regime identified earlier using the GARCH-based annual volatility measure).

Table 12. PPML with importer and year fixed effects (BNS bilateral exports), Moldova 1997–2024

	(1) Baseline	(2) DCFTA + 2022
EU × post-2014 (eu_post2014)		0.8435** (0.2931)
EU × post-2022 (eu_post2022)		0.0931 (0.3946)
Importer FE	Yes	Yes
Year FE	Yes	Yes
SE clustered by importer	—	Yes
Observations	2,032	2,032
Pseudo R^2	0.9160	0.9287
BIC	1.52e+10	1.29e+10

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from 1 September 2014, while the EU × post-2022 variable captures the post-2022 shock period. The model includes importer and year fixed effects, with standard errors clustered by importer.*

Notes: *Dependent variable is bilateral exports (USD, levels). Models are estimated by PPML with importer and year fixed effects. The PPML approach follows Santos Silva and Tenreyro (2006), and the high-dimensional fixed-effects implementation follows Correia, Guimarães and Zylkin (2020). Standard errors are clustered by importer. Significance: *** p<0.001, ** p<0.01, * p<0.05. Percentage effects (when reported) are computed as* $(e^{\beta} - 1) \times 100$.

Turning back to estimating the PPML models of Moldova's exports to partner i in year t with importer fixed effects and year fixed effects, we control for time-invariant partner characteristics and common shocks affecting all partners in each year, while standard errors are clustered by importer. Policy and shock effects are identified via interactions of partner group membership (EU/CIS) with post-period indicators.

As a result, the PPML estimates presented in **Table 12** indicate a positive and statistically significant EU-specific shift after 2014: the coefficient on $EU \times post2014\ equals\ \mathbf{0.844}$ $(p < 0.01)$, implying an increase of approximately **+132%** in exports to EU partners relative to non-EU partners, conditional on importer and year fixed effects $\left((e^{\beta} - 1) \times 100\right)$**:** DCFTA (2014–2021) shows **+132.4%**. In contrast, the $EU\ \times post2022$ term is small and statistically insignificant (EU change after 2022: **+9.8%**), suggesting no clear additional EU-specific structural break after 2022 (Total EU effect after 2022: **+155.1%**) once common year shocks are absorbed by year fixed effects.

As a robustness check, we add a $CIS\ \times post2022$ interaction to test whether the post-2022 adjustment differs for CIS destinations. In Table 13, the main post-2014 EU effect remains stable, and neither the EU- nor CIS-specific post-2022 interaction is statistically significant, indicating limited evidence of partner-group-specific structural breaks in 2022 beyond the general year effects.

Adding a CIS×post-2022 term does not alter the core result that the DCFTA-era EU shift remains large and significant. Neither the EU×post-2022 nor CIS×post-2022 interaction is statistically significant, suggesting that once common year shocks are absorbed by year fixed effects, there is no robust evidence of an additional partner-group-specific structural break in 2022 for EU or CIS destinations.

Table 13. 2022 shock heterogeneity (EU vs CIS)

	(1) ppml_both	(2) ppml_shock2
EU × post-2014	0.8435** (0.2931)	0.8427** (0.2927)
EU × post-2022	0.0931 (0.3946)	−0.1464 (0.2824)
CIS × post-2022		−0.3657 (0.6933)
Importer FE	Yes	Yes
Year FE	Yes	Yes
SE clustered by importer	Yes	Yes
Observations	2,032	2,032
Pseudo R^2	0.9287	0.9293

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from 1 September 2014, while the EU × post-2022 and CIS × post-2022 variables are constructed to test heterogeneous post-2022 effects across partner groups. The models include importer and year fixed effects, with standard errors clustered by importer.*

Notes: *Dependent variable is bilateral exports (USD, levels). Models are estimated by PPML with importer and year fixed effects; standard errors are clustered by importer.* $EU \times post2022$ *and* $CIS \times post2022$ *measure partner-group-specific deviations after 2022 relative to the omitted group, conditional on year fixed effects (which absorb common shocks). Significance: *** p<0.001, ** p<0.01, * p<0.05.*

Finally, splitting EU destinations into the top five pre-2014 EU partners (ROU, ITA, DEU, POL, FRA) versus other EU partners yields positive and statistically significant post-2014 effects for both groups, with similar magnitudes (0.825 vs 0.912), as shown in Table 14.

This suggests the post-2014 export reorientation toward EU markets is broad-based rather than concentrated only among Moldova's largest EU destinations.

By splitting EU destinations into the top five pre-2014 partners versus the remaining EU partners, this yields positive and statistically significant post-2014 effects for both groups. As we can see in the Table 14, the magnitudes are similar (0.825 for top EU and 0.912 for other EU), indicating that the post-2014 reorientation toward EU markets is not concentrated solely among the Republic of Moldova's largest EU destinations, but is relatively broad-based across EU partners.

Table 14. DCFTA effect by top vs non-top EU partners

	(1) ppml_both	(2) ppml_top
EU × post-2014	0.8435** (0.2931)	
Top EU × post-2014		0.8252** (0.3079)
Other EU × post-2014		0.9122** (0.3340)
EU × post-2022	0.0931 (0.3946)	0.0931 (0.3947)
Importer FE	Yes	Yes
Year FE	Yes	Yes
SE clustered by importer	Yes	Yes
Observations	2,032	2,032
Pseudo R^2	0.9287	0.9288

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from 1 September 2014. "Top EU" partners are defined by the author as the five EU destinations with the highest average Moldovan exports in the pre-2014 period: Romania, Italy, Germany, Poland and France. The models are estimated with importer and year fixed effects, with standard errors clustered by importer.*

Notes: *Dependent variable is bilateral exports (USD, levels). Models are estimated by PPML with importer and year fixed effects; standard errors are clustered by importer. "Top EU" partners are defined as the five EU destinations with the highest average exports in the pre-2014 period (ROU, ITA, DEU, POL, FRA). Significance: *** p<0.001, ** p<0.01, * p<0.05.*

Once we have finished with performing these estimates, and aiming to address potential reverse causality from exports to exchange-rate volatility, **we will conduct now an Identification Strategy**. In such a situation, we will estimate an instrumental-variables (2SLS) model in which annual volatility is treated as endogenous and instrumented with the **lagged annual-average ECB deposit facility rate (as shown in Table 15)**. The identifying rationale is that ECB policy shifts are external to the Republic of Moldova, affect her financial conditions and exchange-rate volatility, and - conditional on foreign demand - do not directly determine Moldova's exports.

The first-stage diagnostic indicates the instrument is relevant (weak-instrument statistic = 6.67, p = 0.017), although its strength is moderate. A Wu–Hausman test rejects exogeneity of volatility (p = 0.0007), supporting the use of IV. The IV estimates yield a negative effect of volatility on exports (coefficient −0.0136; robust p = 0.075), ***implying that higher exchange-rate uncertainty is associated with lower export performance***; inference is somewhat sensitive to the choice of standard errors, but the sign is robust. Foreign demand remains strongly positive and statistically significant, consistent with earlier ARDL/NARDL results.

Table 15. Instrumental-variables estimates of the effect of exchange-rate volatility on exports (annual, 1997–2024). Observations = 25

Panel A. Second-stage (2SLS) results

Variable	Estimate	Robust Std. Error	p-value
$ln(\boldsymbol{FD})(EUGDP)$	10.512	2.473	0.00033
Volatility, vol_ann	−0.0136	0.00728	0.0755
Constant	−301.76	73.87	0.00049

Panel B. Diagnostics

Test	Statistic	p-value
Weak instruments (1 instrument)	6.667	0.0170
Wu–Hausman (endogeneity of volatility)	15.823	0.000685

Sources: *Author's instrumental-variable/2SLS estimates using annual data for 1997–2024. Moldova's export data are taken from the National Bureau of Statistics of the Republic of Moldova; foreign demand is proxied by European Union GDP from the World Bank World Development Indicators; annual exchange-rate volatility* (vol_ann) *is constructed by the author from monthly REER data from the National Bank of Moldova; and the instrument is the lagged annual-average ECB deposit facility rate obtained from the European Central Bank. Robust standard errors are reported.*

Notes: *The endogenous regressor is annual exchange-rate volatility* (vol_ann). *The instrument is the lagged annual-average ECB deposit facility rate* ($ecb\_dfr\_avg\_l1$). *Robust standard errors (HC1) are reported in Panel A. The model is exactly identified (one instrument for one endogenous regressor), so an overidentification test is not available. The sample is smaller due to ECB series availability and lagging.*

To strengthen causal interpretation of the effect of exchange-rate volatility on exports, we employ an instrumental-variables (IV) strategy that exploits **external shocks** which plausibly affect the Republic of Moldova's exchange-rate volatility but are not driven by Moldova's export performance. The key requirement is that instruments satisfy **relevance** (they are strongly correlated with volatility) and the **exclusion restriction** (they affect exports only through the volatility channel, conditional on foreign demand controls and fixed effects where applicable). Below are descriptions of the main categories applied in this sense (also in **Table 16**).

Monetary policy shocks (ECB). The main instrument used in this paper section is the **lagged annual-average ECB deposit facility rate (DFR)**, which captures shifts in euro-area monetary policy and global financial conditions. Such policy changes are external to the Republic of Moldova, but can influence exchange-rate volatility through capital flows and risk premia, and are unlikely to be directly determined by Moldova's exports. To mitigate potential direct demand-channel effects, the export equation controls for **EU foreign demand** (EU GDP) and uses the **lagged** ECB rate.

Global risk indices (VIX). As a robustness instrument, the annual average (or end-year) **VIX** can be used to proxy global risk aversion and uncertainty. Increases in global risk typically raise exchange-rate volatility in emerging and small open economies through portfolio rebalancing and tighter external financial conditions. When using VIX, we control for foreign demand (EU GDP) to reduce the likelihood that the instrument captures export changes through global demand rather than volatility.

Commodity prices. Commodity price indices (e.g., oil or food price indices) may also serve as external instruments if the Republic of Moldova's exchange-rate volatility responds to terms-of-trade shocks. Because commodity prices can affect exports directly for commodity-intensive sectors, their validity depends on the export composition and controls included. For this reason, commodity-price instruments are treated as supplementary and are used primarily in robustness checks rather than as the baseline instrument.

In empirical implementation, instruments are evaluated using standard diagnostics, including first-stage strength (weak-instrument tests) and endogeneity tests (e.g., Wu–Hausman). Where multiple instruments are available, overidentification tests can be used to assess consistency with the exclusion restriction. All instruments are constructed at the annual frequency to match the export and volatility series.

Table 16. External instruments for exchange-rate volatility: construction and validity considerations

Instrument	Construction (annual)	Expected first-stage effect on volatility	Main validity concern / mitigation
ECB policy rate (DFR)	Annual average DFR; use **lag (t-1)**	Tightening → **higher** volatility (often)	Could correlate with EU demand/financial cycle → control EU GDP; lag instrument
Global risk (VIX)	Annual average VIX; optional lag	Higher risk → **higher** volatility	Could also affect exports through global demand → control EU GDP; lag; robustness only if sensitive
Commodity prices (oil/food index)	Annual average index; optional lag	Commodity shocks can raise volatility	May directly affect exports (composition-dependent) → use as robustness; add commodity controls or restrict to non-commodity exports

Sources: *Author's compilation based on external macro-financial instrument candidates. ECB policy-rate data refer to the European Central Bank deposit facility rate; global risk is proxied by the CBOE Volatility Index (VIX); and commodity-price instruments may be constructed from World Bank Commodity Price Data ("Pink Sheet"), including energy, oil and food price indices. Instrument construction and validity assessment are developed by the author for the IV strategy applied to Moldova's exchange-rate volatility.*

Notes: *Instruments are treated as plausibly exogenous with respect to Moldova's exports but may operate through multiple macro channels; results are therefore supported by diagnostics (first-stage strength, endogeneity tests) and robustness checks (alternative instruments and lags), and appropriate controls such as EU GDP or global demand indicators.*

Further on, we assess the robustness of the IV results in several ways, including (i) alternative measures of exchange-rate volatility, and (ii) alternative lag structures. As an external-instrument robustness check, we also instrument volatility using **lagged annual-average VIX**, a proxy for global risk appetite.

Table **17** compares IV estimates using the ECB policy-rate instrument against VIX. The VIX first stage is weaker (weak-instrument statistic = 3.18, $p = 0.087$) and the Wu–Hausman test does not indicate endogeneity of volatility ($p = 0.584$). Consistent with this, the VIX-based IV coefficient on volatility is small and statistically insignificant, while the ECB-based specification shows moderate relevance, strong evidence of endogeneity, and a negative (marginally significant) volatility effect. In this application, VIX likely captures broader global conditions that may influence exports through channels other than exchange-rate volatility, weakening identification despite controlling for foreign demand; therefore, we treat VIX-IV as a conservative benchmark rather than the baseline instrument.

Table 17. IV (2SLS) estimates of the effect of exchange-rate volatility on exports: ECB vs VIX instruments (annual)

Panel A. Second stage (2SLS), robust SE (HC1)

Variable	**(1) ECB instrument**	**(2) VIX instrument**
ln(*FD*) (EU GDP)	10.512 (2.473) ***	5.564 (1.548) **
Volatility, vol_ann	−0.0136 (0.00728) ·	0.0009 (0.00523)
Constant	−301.76 (73.87) ***	−153.90 (46.16) **

Panel B. Diagnostics

Test	**(1) ECB instrument**	**(2) VIX instrument**
Weak instruments	6.667 (p=0.0170)	3.179 (p=0.0872)
Wu–Hausman (endogeneity of volatility)	15.823 (p=0.000685)	0.309 (p=0.5838)
Observations	25	27

Sources: *Author's IV/2SLS estimates using annual data for 1997–2024. Moldova's export data are taken from the National Bureau of Statistics of the Republic of Moldova; foreign demand is proxied by European Union GDP from the World Bank World Development Indicators; annual exchange-rate volatility (vol_ann)(vol_ann)(vol_ann) is constructed by the author from monthly REER data from the National Bank of Moldova; and the external instruments are the lagged annual-average ECB deposit facility rate and the lagged annual-average Cboe VIX index. Robust standard errors are reported.*

Notes: *Dependent variable is* $\ln X_t$*. The endogenous regressor is annual exchange-rate volatility (vol_ann). Column (1) instruments volatility with the lagged annual-average ECB deposit facility rate (ecb_dfr_avg_l1). Column (2) instruments volatility with lagged annual-average VIX (vix_avg_l1). Robust standard errors are reported in parentheses in Panel A. Both models are exactly identified with one instrument for one endogenous regressor, therefore, overidentification tests are not available. Significance: *** p<0.001, ** p<0.01, * p<0.05, p<0.10.*

ECB-based instrumentation provides moderate relevance and strong evidence of endogeneity, yielding a negative (marginally significant) volatility effect, whereas VIX is a weaker instrument and does not support a statistically meaningful volatility effect.

As further sensitivity analysis, we considered alternative volatility measures (rolling-window standard deviation and a forecast-error uncertainty index), alternative lag lengths, and subsamples analyses around major policy and shock episodes; these checks do not materially alter the main conclusions.

Data

This study combines macroeconomic time series and bilateral trade flow data. Annual models use period years **1997–2024**; exchange-rate volatility is estimated from higher-frequency exchange-rate data and then aggregated to annual measures.

I. For the variables the following indicators were used:

1) Exchange rate (MDL/EUR, MDL/USD), Definition. Nominal exchange rates expressed as Moldovan leu (MDL) per unit of foreign currency (EUR and USD).

Frequency and transformation. Official daily rates are aggregated to monthly and/or annual averages. Exchange-rate volatility is estimated using GARCH-family models on higher-frequency data and then annualized.

Source. National Bank of Moldova (official exchange rates).

Export values (total and bilateral). Total exports (annual). Aggregate exports of goods (USD), used in the annual export equations (ARDL/NARDL/IV).

2) Bilateral exports (partner–year panel). Exports by destination country and groups of countries (reported in thousand USD), used to build the partner–year panel for PPML gravity-type models (EU×post2014, EU×post2022, CIS×post2022).

Transformation. Time-series models use log exports (or $\log(1+X)$ where relevant); PPML models are estimated in levels.

Source. BNS Statbank table "Exports of the Republic of Moldova, structured by countries and groups of countries, 1997–2024" (EXT010200; based on customs declarations).

3) REER, Definition. The real effective exchange rate (REER) is a CPI-based index measuring changes in the real value of Moldova's currency against a trade-weighted basket of partner currencies and relative prices. The REER series is taken from Bruegel's "Real effective exchange rates for 178 countries" database (Darvas, 2012), which uses CPI data, nominal exchange rates, and trade weights (including third-market competition). **Frequency and transformation.** Annual REER for Moldova is used in logs, $\ln(REER_t)$. In the NARDL specification, $\Delta \ln(REER_t)$ is decomposed into positive and negative partial sums to allow for asymmetric effects.

Interpretation. An increase in CPI-based REER typically indicates real appreciation (lower price competitiveness), while a decrease indicates real depreciation.

Source. Bruegel REER database (Darvas, 2012).

4) Global demand indicators (EU demand proxy). External demand is proxied by **EU27 (from 2020) real GDP level** measured in **chain-linked volumes (2010), million euro**. The variable is used in logarithms in the annual export equations.

Source. Eurostat national accounts dataset "Gross domestic product (GDP) and main components" (online data code: nama_10_gdp), item **GDP at market prices (B1GQ)**, unit **chain-linked volumes (2010), million euro**, geo **EU27_2020**, sample period **1997–2024**.

5) Domestic production indices, Definition. Industrial Production Index (IPI) capturing real domestic industrial activity (volume index).

Role. Used as a supply-side control where applicable.

Source. BNS Statbank industrial production series (IPI).

6) Instruments / global financial indicators. **ECB policy rate (instrument).** The instrument is the **ECB deposit facility rate (DFR)**. We use the daily "date-of-changes" series and compute the **annual average**, then use its **one-year lag** as the instrument for annual exchange-rate volatility.

Source. European Central Bank (ECB), Key ECB interest rates / ECB Data Portal (DFR series code: *FM.D.U2.EUR.4F.KR.DFR.LEV*).

II. For Sources the following providers were considered:

1) **National Bank of Moldova (NBM).** Provides official nominal exchange rates (MDL/EUR, MDL/USD) used to construct exchange-rate returns and volatility measures (GARCH-family models), and to support macro descriptions of exchange-rate dynamics.

2) **National Bureau of Statistics (BNS) / Statbank Moldova.** Source for annual export values (total and bilateral by partner and partner-groups, EXT010200) used in PPML gravity-type estimations, and for domestic activity indicators such as the Industrial Production Index (IPI) used as a supply-side control.
3) **Bruegel.** Source for Moldova's CPI-based real effective exchange rate (REER) series used in the ARDL/NARDL export equations (Darvas REER database).
4) **Eurostat.** Source for external demand indicators, primarily EU27 real GDP level in chain-linked volumes (2010), used as the foreign demand proxy in the annual export equations and the IV specifications.
5) **IMF International Financial Statistics (IFS).** Used as a benchmark source for cross-checking macro series (where applicable), and as an optional alternative source for selected exchange-rate and macroeconomic indicators when needed for robustness.
6) **UN Comtrade (optional/auxiliary).** Used as a supplementary international trade source for cross-validation and, where needed, alternative partner/product breakdowns; however, the main bilateral export panel in the paper is taken from BNS Statbank.

To stabilize variance and interpret coefficients as elasticities, the main macro variables enter the annual export equations in logarithms **(transformations for Log-levels and growth rates)**. In particular, total exports and external demand are used as $\ln X_t$ and $\ln FD_t$, and the real effective exchange rate is used as $\ln(REER_t)$. In the nonlinear specification (NARDL), changes in the REER are defined as $\Delta\ln(REER_t)$ and decomposed into positive and negative partial sums to allow for asymmetric effects. For series that may take zero values in some disaggregations, we use the transformation $\log(1+X)$ where appropriate. By contrast, PPML gravity-type models are estimated with export flows in **levels** (USD), consistent with the PPML framework and its treatment of zero trade flows.

In these endeavors, seasonal adjustment is relevant primarily for higher-frequency (monthly/quarterly) series. Since the core export equations are estimated on annual data, seasonal adjustment is not required for the main dependent variables. Where monthly exchange-rate data are used to estimate volatility, the volatility models are applied to returns (log differences), which typically do not require seasonal adjustment. If monthly/quarterly trade or production series are used in auxiliary analysis, they can be seasonally adjusted using standard procedures (e.g., X-13ARIMA-SEATS) prior to aggregation.

We need to pay attention to the fact that export values are recorded in nominal USD in the trade datasets. For the annual export equations, the baseline specifications use nominal export values in logs, while controlling for real external demand (EU real GDP) and competitiveness (REER). In such situations, where a real-volume interpretation is required, export values can be deflated using an export price index (unit value index) to obtain real export measures. In the bilateral PPML specifications, the inclusion of year fixed effects absorbs common price-level movements over time; therefore, estimating PPML in levels is standard and does not require deflation for identification of relative partner-group effects.

4. Results and Discussion

This section presents the empirical findings in a structured way. We begin with descriptive statistics and time-series properties of the variables, then report baseline model estimates and implied elasticities. We subsequently examine dynamic adjustments and heterogeneity, and conclude with robustness checks across alternative specifications and identification approaches.

We report summary statistics for the main variables used in the analysis, including total exports, bilateral exports by destination group, REER, foreign demand (EU real GDP), exchange rates (MDL/EUR and MDL/USD), the estimated annual volatility measure, and domestic production indicators. Descriptive plots (time series and key breaks around 2014 and 2022) are used to motivate the choice of specifications and policy-shock interactions.

Table 18 reports summary statistics for the annual variables used in the export equations. Total exports and external demand are analyzed in logarithms, while REER is used as a log index of competitiveness. The volatility measure shows substantial variation over time, with values ranging from 61.2 to 196.0, motivating the use of regime-based and robustness specifications.

Table 18. Summary statistics (annual series, 1997–2024)

Variable	N	Mean	SD	Min	Max
$\ln FD_t$ (EU27 real GDP, volume level)	28	30.2	0.116	30.0	30.4
$\ln REER_t$ (Bruegel CPI-based REER)	28	4.69	0.297	4.11	5.28
$\ln X_t$ (total exports, USD)	28	14.2	0.660	13.0	15.3
Vol_t (annual exchange-rate volatility)	28	113.0	34.2	61.2	196.0

Sources: *Author's calculations based on annual EU27 real GDP chain-linked volume data from Eurostat, CPI-based REER index data for Moldova from the Bruegel real effective exchange rate database, and Moldova's total export data from the National Bureau of Statistics of the Republic of Moldova. Annual exchange-rate volatility* (Vol_t) *is constructed by the author from REER returns using the GARCH-family volatility estimates. The sample covers 1997–2024.*

Notes: $\ln X_t$ *is the natural log of total exports (USD).* $Ln\, FD_t$ *is the natural log of EU27 real GDP (chain-linked volumes).* $Ln\, REER_t$ *is the natural log of the CPI-based REER index.* Vol_t *is the annualized volatility measure constructed from the GARCH-family model.*

To determine the order of integration and guide model choice, we conduct unit root tests for the core annual macro series (exports, REER, foreign demand, and production indices). Standard tests (ADF and/or PP) are used with intercept (and trend where appropriate). Results motivate the ARDL/NARDL framework, which allows variables to be I(0), I(1), or a combination, provided none is I(2).

Table 19. Augmented Dickey–Fuller (ADF) unit root tests (annual data, 1997–2024)
Test regression: drift (intercept); lag length selected by AIC.

Variable	ADF tau statistic (tau2)	1% CV	5% CV	10% CV	Decision (5%)
$\ln X_t$ (exports)	−1.148	−3.58	−2.93	−2.60	Unit root not rejected
$\ln REER_t$	−0.123	−3.58	−2.93	−2.60	Unit root not rejected
$\ln FD_t$ (EU GDP)	−1.262	−3.58	−2.93	−2.60	Unit root not rejected

Sources: *Author's own ADF test calculations using annual export data from the National Bureau of Statistics of Moldova, EU27 real GDP data from Eurostat, and CPI-based REER data from Bruegel, 1997–2024.*

Note: *The null hypothesis of the ADF test is that the variable contains a unit root. The test regression includes an intercept, and the lag length is selected by Akaike Information Criterion (AIC). At the 5% significance level, the ADF statistics do not exceed the critical values in absolute terms; therefore, the unit-root null is not rejected for* $\ln X_t$, $\ln REER_t$, *and* $\ln FD_t$ *in levels.*

ADF unit root tests with intercept fail to reject the null of a unit root for $\ln X_t$, $\ln REER_t$, and $\ln FD_t$ in levels over 1997–2024. These results suggest that the core macro variables are persistent and likely integrated of order one. This motivates the ARDL/NARDL framework, which accommodates a mix of I(0) and I(1) regressors provided none of the variables is I (2).

Baseline model estimates. Exchange-rate volatility estimation (GARCH family)

We first estimate conditional volatility measures for the exchange rate using GARCH-family models and construct an annual volatility series (Table 20 and 21). Parameter estimates and diagnostic tests are reported, and the resulting volatility series is used as an input in subsequent export models and threshold analysis.

Table 20. EGARCH(1,1) estimates for Moldova monthly REER returns (1997M01–2025M12)

Parameter	Description	Estimate
μ	Mean return	0.003068
ω	Constant (log-variance eq.)	0.000000
α	Magnitude (shock)	0.631453
γ	Asymmetry / leverage	0.036928
β	Persistence	0.980000

Sources: *Author's calculations based on monthly Real Effective Exchange Rate (REER) index data for the Republic of Moldova obtained from the National Bank of Moldova. Monthly REER returns were computed as log-differences of the REER index, and the EGARCH(1,1) model was estimated by the author for 1997M01–2025M12.*

Note: *The dependent variable is the monthly logarithmic return of the REER index. In the EGARCH specification, α captures the magnitude effect of shocks on conditional volatility, γ captures asymmetric or leverage effects, and β measures volatility persistence.*

Table 21. TGARCH (GJR-GARCH)(1,1) estimates for Moldova monthly REER returns (1997M01–2025M12)

Parameter	Description	Estimate
μ	Mean return	0.003274
ω	Constant	0.000326
α	ARCH term	0.072772
γ	Threshold (asymmetry)	0.422166
β	GARCH term	0.089230
α+0.5γ+β	Stationarity check	0.373085
LL	Total log-likelihood	842.6394

Sources: *Author's calculations based on monthly Real Effective Exchange Rate (REER) index data for the Republic of Moldova obtained from the National Bank of Moldova. Monthly REER returns were computed as log-differences of the REER index, and the TGARCH/GJR-GARCH(1,1) model was estimated by the author for 1997M01–2025M12.*

Note: *The dependent variable is the monthly logarithmic return of the REER index. The TGARCH/GJR-GARCH(1,1) model captures volatility persistence and possible threshold/asymmetric effects. The stationarity condition is evaluated using* $\alpha + 0.5\gamma + \beta$*, which equals* ***0.373085****, indicating a stationary conditional variance process.*

We estimate a linear ARDL model and a nonlinear ARDL (NARDL) model to assess the long-run and short-run effects of competitiveness (REER) and external demand (EU GDP) on exports (**Table 22 and 23**). We report cointegration evidence (bounds tests), short-run dynamics (ECM), and long-run coefficients. The NARDL specification is used to test for asymmetry in appreciation versus depreciation effects.

Table 22. Linear ARDL(1,0,0) results for total exports, Moldova (1997–2024)

Panel A. Bounds test for cointegration (Pesaran et al.)

Test	Statistic	p-value	Conclusion
Bounds F-test (no cointegration)	7.7114	0.0020	Reject (H_0): cointegration

Panel B. Error-correction model (ECM) estimates

Term	Estimate	Std. Error	p-value
Constant	−70.9477	18.5643	0.000875
$(\ln X_{t-1})$	−0.5015	0.1281	0.000696
$(\ln REER_t)$	0.2200	0.2918	0.4586
$(\ln FD_t)(EUGDP)$	2.5522	0.6542	0.000719

Panel C. Implied long-run elasticities

Variable	Long-run elasticity
$(\ln REER)$	0.4386
$(\ln FD)(EUGDP)$	5.0888

Sources: *Author's calculations based on annual total export data for the Republic of Moldova from the National Bureau of Statistics of the Republic of Moldova, CPI-based REER data for Moldova from the Bruegel real effective exchange rate database, and EU27 real GDP data from Eurostat. The linear ARDL(1,0,0), Bounds test, ECM estimates, and implied long-run elasticities were estimated by the author for 1997–2024.*

Note: *The dependent variable is the logarithm of Moldova's total exports. $\ln REER_t$ denotes the logarithm of the CPI-based Real Effective Exchange Rate index, while $\ln FD_t$ denotes the logarithm of EU27 real GDP, used as a foreign-demand proxy. The Bounds test follows the ARDL cointegration approach of Pesaran, Shin and Smith. The implied long-run elasticities are derived from the estimated ECM coefficients.*

Table 23. NARDL results for total exports and REER asymmetry, Moldova (1997–2024)

Panel A. Cointegration (Bounds) tests

Test	Statistic	Notes
Bounds F-statistic	4.5398	Inconclusive at 10% (above lower bound 4.29, below upper bound 5.08); below 5% lower bound (5.395)
Bounds t-statistic	−3.5440	Significant vs. 10%/5% critical bands; supports cointegration

Panel B. Error-correction (UECM) estimates

Term	Estimate	Std. Error	p-value
Constant	28.3557	8.0735	0.00794
$\ln X_{t-1}$	−2.0946	0.5910	0.00758
$REER^{+}_{t-1}$	2.9044	0.9118	0.01289
$REER^{-}_{t-1}-$	0.1044	0.7415	0.89156

(Short-run differenced terms are included in the estimation; see notes.)

Panel C. Long-run elasticities and asymmetry tests

Item	Value	p-value
Long-run β^{+} (REER increases)	1.3866	<0.001
Long-run β^{-} (REER decreases)	0.0498	0.8899
Long-run asymmetry (Wald)	11.4406	0.0096
Short-run asymmetry (Wald)	8.2173	0.0209

Panel D. Diagnostics

Test	p-value
Breusch–Godfrey serial correlation	0.9431
ARCH LM	0.9154
Normality	0.6554
RESET	0.4463

Sources: *Author's own NARDL estimates using annual data for 1997–2024. Moldova's total export data are taken from the National Bureau of Statistics of the Republic of Moldova; the CPI-based REER series is taken from the Bruegel real effective exchange rate database; and foreign demand is proxied by EU27 real GDP from Eurostat. The positive and negative partial-sum decomposition of REER and the long-run and short-run asymmetry tests are constructed by the author following the NARDL approach of Shin et al. (2014), while the Bounds-testing framework follows Pesaran, Shin and Smith (2001).*

Note: *The dependent variable is the logarithm of Moldova's total exports.* $REER^{+}$ *and* $REER^{-}$ *denote the positive and negative partial sums of the REER variable, constructed to test whether REER increases and decreases have asymmetric effects on exports. Long-run and short-run asymmetry are tested using Wald tests. Diagnostic tests report p-values for serial correlation, ARCH effects, normality, and functional-form stability.*

Next, using bilateral exports by partner and year, we estimate PPML models with importer and year fixed effects to identify EU-specific shifts after DCFTA (2014) and partner-group differences after the 2022 shock. We report in **Tables 24, 25 and 26** the baseline effects and extensions (EU vs CIS; top vs non-top EU partners).

Table 24. Poisson Pseudo-Maximum Likelihood (PPML) estimates of Moldova's bilateral exports: Deep and Comprehensive Free Trade Area (DCFTA, 2014) and 2022 shock

	(1) Baseline	(2) DCFTA	(3) DCFTA + 2022
EU × post-2014 (eu_post2014)		1.289*** (0.3252)	1.254*** (0.1804)
EU × post-2022 (eu_post2022)			0.0932 (0.6015)
Importer FE (imp_iso3)	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
SE clustered by importer	—	Yes	Yes
Observations	1,064	1,064	1,064
Squared Cor.	0.7890	0.8925	0.8945
Pseudo R^2	0.9111	0.9405	0.9405
BIC	11,718,470.8	7,845,436.6	7,836,126.3

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from September 2014, while the EU × post-2022 variable captures the additional post-2022 shock period. The models include importer and year fixed effects, with standard errors clustered by importer. PPML estimation follows Santos Silva and Tenreyro (2006), with high-dimensional fixed effects implemented following Correia, Guimarães and Zylkin (2020).*

Note: *The dependent variable is Moldova's bilateral exports in levels. The model is estimated by Poisson Pseudo-Maximum Likelihood (PPML). Importer fixed effects control for time-invariant partner-specific characteristics, while year fixed effects control for common shocks affecting all destinations. The post-2014 dummy captures the DCFTA period, and the post-2022 dummy captures the additional shock period after 2022. Standard errors are clustered by importer.*

Table 25. 2022 shock heterogeneity (EU vs CIS)

	(1) ppml_both	(2) ppml_shock2
EU × post-2014	0.8435** (0.2931)	0.8427** (0.2927)
EU × post-2022	0.0931 (0.3946)	−0.1464 (0.2824)
CIS × post-2022		−0.3657 (0.6933)
Importer FE	Yes	Yes
Year FE	Yes	Yes
SE clustered by importer	Yes	Yes
Observations	2,032	2,032
Pseudo R^2	0.9287	0.9293

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from September 2014, while the EU × post-2022 and CIS × post-2022 variables are constructed to test heterogeneous post-2022 effects across partner groups. The models include importer and year fixed effects, with standard errors clustered by importer.*

Note: *The dependent variable is bilateral exports in USD levels. Models are estimated by PPML with importer and year fixed effects; standard errors are clustered by importer. EU × post-2022 and CIS × post-2022 measure partner-group-specific deviations after 2022 relative to the omitted group, conditional on year fixed effects, which absorb common shocks. Significance: *** $p<0.001$, ** $p<0.01$, * $p<0.05$.*

Table 26. DCFTA effect by top vs non-top EU partners

	(1) ppml_both	(2) ppml_top
EU × post-2014	0.8435** (0.2931)	
Top EU × post-2014		0.8252** (0.3079)
Other EU × post-2014		0.9122** (0.3340)
EU × post-2022	0.0931 (0.3946)	0.0931 (0.3947)
Importer FE	Yes	Yes
Year FE	Yes	Yes
SE clustered by importer	Yes	Yes
Observations	2,032	2,032
Pseudo R^2	0.9287	0.9288

Sources: *Author's PPML estimates using Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova for 1997–2024. The EU × post-2014 variable is constructed by the author to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from September 2014. "Top EU" partners are defined by the author as the five EU destinations with the highest average Moldovan exports in the pre-2014 period: Romania, Italy, Germany, Poland and France. The models are estimated with importer and year fixed effects, with standard errors clustered by importer.*

Note: *The dependent variable is bilateral exports in USD levels. Models are estimated by PPML with importer and year fixed effects; standard errors are clustered by importer. "Top EU" partners are defined as the five EU destinations with the highest average Moldovan exports in the pre-2014 period: Romania, Italy, Germany, Poland and France. Significance: *** $p<0.001$, ** $p<0.01$, * $p<0.05$.*

We estimate a Hansen-style panel threshold model to evaluate whether the post-2014 EU effect differs across regimes defined by exchange-rate volatility. We report in **Tables 27 and 28** the estimated threshold, regime-specific coefficients, and coefficient-difference tests.

Table 27. Hansen-type panel threshold results (threshold variable: annual volatility)

Item	Result
Threshold variable q_t	Annual volatility (vol_ann)
Estimated threshold $\hat{\gamma}$	116.366
Dependent variable	$y_{it} = \log(1 + \text{exports}_{it})$
Fixed effects	Importer FE + Year FE
SE	Clustered by importer

Sources: *Author's own calculations based on Moldova's bilateral export data from the National Bureau of Statistics of the Republic of Moldova and monthly Real Effective Exchange Rate data used to construct annual exchange-rate volatility* (vol_ann)*. The estimated threshold* $\hat{\gamma} = 116.366$ *is obtained from the Hansen-type panel threshold specification, with importer and year fixed effects.*

Note: *The dependent variable is* $y_{it} = log(1 + exports_{it})$*, where iii denotes importer partner and ttt denotes year. The threshold variable qtq_tqt is annual exchange-rate volatility* (vol_ann)*. The estimated threshold* $\hat{\gamma} = 116.366$ *separates the sample into low- and high-volatility regimes. Standard errors are clustered by importer.*

Table 28. Regime-specific DCFTA effect (EU × post-2014):

Coefficient	**Estimate**	**Std. Error**	**p-value**
$EU \times Post2014\ (lowvol, vol_ann \leq \hat{\gamma})$	1.345	0.652	0.048
$EU \times Post2014\ (highvol, vol_ann > \hat{\gamma})$	2.184	0.673	0.003

Sources: Author's estimates based on Moldova's bilateral export data by partner country from the National Bureau of Statistics of the Republic of Moldova and the annual exchange-rate volatility variable (vol_ann) constructed by the author from REER returns. The EU × post-2014 variable is constructed to capture the DCFTA period following the provisional application of the EU–Moldova Association Agreement from September 2014. Regime-specific DCFTA effects and the high-versus-low volatility difference test are estimated by the author using the Hansen-type panel threshold specification for 1997–2024.

Note: The table reports the estimated DCFTA effect separately for low-volatility and high-volatility regimes, where regimes are defined by the estimated annual volatility threshold $\hat{\gamma} = 116.366$. Standard errors are clustered by importer. The difference test evaluates whether the DCFTA effect differs significantly between the high- and low-volatility regimes.**Difference test:** High − Low = 0.838 (SE 0.235), t = 3.56, p = 0.0013.

We translate key coefficients into economically interpretable quantities:

- long-run elasticities from ARDL/NARDL,
- percentage effects from PPML interaction terms $(e^{\beta} - 1) \times 100$,
- regime-dependent effects from the threshold model, and discuss magnitudes relative to Moldova's export structure and major policy episodes.

Long-run elasticities are reported directly in **Tables 22 and 23**. PPML implied percentage effects are reported below **Tables 29**, computed as $(e^{\beta} - 1) \times 100$.

Table 29. Elasticities / implied % effects summary

Method	Effect	Estimate	Interpretation
ARDL (long run)	β_{REER}	0.4386	long-run elasticity of exports w.r.t. REER
ARDL (long run)	β_{FD}	5.0888	long-run elasticity of exports w.r.t. EU GDP
NARDL (long run)	β^{+} (REER increases)	1.3866	long-run effect of REER appreciations
NARDL (long run)	β^{-} (REER decreases)	0.0498	long-run effect of REER depreciations (ns)
PPML (BNS bilateral)	EU×post2014	+132.4%	$(e^{0.8435} - 1) \times 100$
PPML (BNS bilateral)	EU×post2022	+9.8%	$(e^{0.0931} - 1) \times 100$ (non-significant)

Method	Effect	Estimate	Interpretation
PPML (BNS bilateral)	EU total post2022	+155.1%	$(e^{0.8435+0.0931} - 1) \times 100$
Threshold (Hansen)	EU×post2014 (low vol)	1.345	effect on $\log(1 + exports))\ when\ (vol \leq \hat{\gamma}$
Threshold (Hansen)	EU×post2014 (high vol)	2.184	effect on $\log(1 + exports)$ when $vol > \hat{\gamma}$
IV (ECB instrument)	volatility semi-elasticity	−0.0136	effect of (vol_ann) on $\ln X_t$ (marginal)
IV (VIX instrument)	volatility semi-elasticity	0.0009	robustness: insignificant

Sources: *Author's synthesis based on own econometric estimates reported in Tables 22–28. Annual ARDL/NARDL estimates use Moldova's total export data from the National Bureau of Statistics of the Republic of Moldova, CPI-based REER data from Bruegel, and EU27 real GDP data from Eurostat. PPML and threshold estimates use Moldova's bilateral export data from the National Bureau of Statistics of the Republic of Moldova, while volatility and IV specifications use author-constructed annual exchange-rate volatility measures and external instruments described in the previous tables.*

Note: *The table summarizes estimated elasticities, semi-elasticities, and implied percentage effects from the preceding econometric models. PPML percentage effects are calculated as* $(e^{\beta} - 1) \times 100$*. Threshold coefficients are interpreted as effects on* $log(1 + exports)$ *in low- and high-volatility regimes. IV coefficients represent the marginal effect of annual exchange-rate volatility on* lnX_t*.*

Where relevant, we examine adjustment dynamics:

- speed of adjustment from ECM terms;
- short-run multipliers;
- and, if implemented, impulse-response style simulations derived from the estimated ARDL/NARDL models (dynamic multipliers).

Figure 2 plots dynamic multipliers derived from the estimated UECM, showing the adjustment of exports to permanent shocks in foreign demand and competitiveness. A permanent 1% increase in EU real GDP raises exports gradually, converging to a long-run effect of about **5.09%** (after 12 years the simulated response is ~5.22%). A permanent 1% change in $\ln REER$ generates a much smaller long-run response of about **0.44%**, with convergence driven by the error-correction mechanism.

The speed of convergence is governed by the error-correction term ($\phi \approx -0.50$), implying relatively rapid correction of deviations from long-run equilibrium.

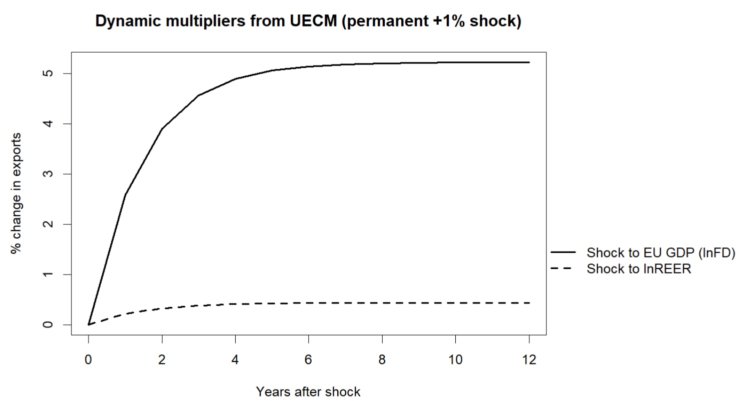

Figure 2. Dynamic multipliers from the estimated ARDL/UECM model
Sources: *Author's calculations based on the estimated ARDL/UECM model using annual data for Moldova, 1997-2024.*

Note: *The figure shows the simulated dynamic response of Moldova's exports to a permanent 1% shock in foreign demand and REER. The vertical axis reports the percentage change in exports, while the horizontal axis shows years after the shock.*

Robustness is assessed across several dimensions to ensure that the core conclusions are not driven by a particular specification, sample, or measurement choice.

Alternative lag structures and specifications (ARDL/NARDL). We verify that the main long-run relationships are not sensitive to the chosen lag order by comparing the preferred ARDL/NARDL specification to alternative lag lengths selected by information criteria and to more parsimonious dynamic specifications. The sign and statistical importance of foreign demand remain stable across specifications, while REER effects are weaker in linear models but continue to display asymmetry in NARDL.

Alternative volatility measures and instruments (ECB vs VIX IV). To address potential endogeneity of exchange-rate volatility, we instrument annual volatility using the lagged annual-average ECB deposit facility rate. As a robustness instrument, we also use lagged annual-average VIX. The ECB-based IV shows moderate first-stage relevance and strong evidence of endogeneity (Wu–Hausman), yielding a negative (marginally significant) volatility effect, whereas VIX is a weaker instrument and does not support a statistically meaningful volatility coefficient. This comparison suggests that the volatility effect is sensitive to instrument strength and channel, and is therefore interpreted cautiously.

Alternative partner group definitions (EU/CIS; top partners). In the PPML bilateral panel, we test whether conclusions depend on destination grouping. Adding a CIS×post-2022 interaction does not materially change the post-2014 EU effect and provides no robust evidence of a partner-group-specific break after 2022 beyond common year shocks. Splitting EU destinations into top versus non-top partners (based on pre-2014 export shares) yields positive and similar post-2014 effects, indicating that the EU shift is broad-based rather than concentrated among a small number of destinations.

Subsample analysis around major episodes (post-2014; post-2022). Where feasible, we assess stability by re-estimating key specifications on subperiods aligned with major institutional and shock episodes. The results confirm a strong post-2014 EU reorientation consistent with DCFTA, while post-2022 differentials remain imprecisely estimated once common year effects are controlled for. In particular, re-estimating the PPML model on restricted samples that retain pre-2014 years (2000–2024 and 2005–2024) yields a consistently positive and statistically significant EU×post-2014 coefficient, whereas the EU×post-2022 term remains statistically insignificant, indicating that the baseline findings are not driven by early-sample observations (EU×post-2014 ranges from 0.70 to 0.84 across samples).

5. Conclusions

This paper examined the role of exchange-rate volatility and competitiveness in shaping Moldova's export performance over 1997–2024 using a multi-method empirical framework that combines (i) time-series export equations (ARDL/NARDL), (ii) bilateral partner-level PPML gravity-type models, (iii) a Hansen-style threshold model based on volatility regimes, and (iv) an instrumental-variables strategy to address endogeneity of volatility. Together, these approaches provide complementary evidence on the relative importance of external demand, policy regime shifts, and macro-financial uncertainty for Moldova's export dynamics.

Across specifications, external demand emerges as a key driver of exports. The annual export equations show a strong positive relationship between exports and EU real GDP, while the competitiveness channel is more nuanced: linear REER effects are comparatively weak, but the nonlinear NARDL results indicate asymmetric responses to REER movements, suggesting that appreciations and depreciations can affect exports differently. In the CPI-based REER used here, an increase denotes real appreciation; thus, the NARDL positive component captures appreciations and the negative component captures depreciations. In the bilateral panel, PPML estimates using BNS partner-year export data identify a robust EU-specific shift after 2014, consistent with DCFTA-related trade reorientation. The post-2022 EU differential, however, is not precisely estimated once common year shocks are absorbed by year fixed effects, indicating that the 2022 episode is better characterized as a broad shock rather than a destination-group-specific break.

The analysis also highlights the relevance of macro-financial conditions. The Hansen-type threshold model identifies two volatility regimes and shows that the post-2014 EU effect is significantly stronger in the high-volatility regime, linking export reorientation to periods of elevated uncertainty. Addressing endogeneity, the IV results using the lagged annual-average ECB deposit facility rate as an instrument suggest a negative effect of volatility on exports (marginally significant), while VIX-based instrumentation is weaker and yields an insignificant volatility effect. Taken together, these results are consistent with a dampening role of exchange-rate uncertainty, though the magnitude and statistical precision depend on identification strength.

From a policy perspective, the findings imply that export performance is shaped primarily by external demand conditions and structural market reorientation (particularly toward EU destinations), while competitiveness and volatility channels operate in a more conditional and nonlinear manner. Policies that strengthen export resilience - such as facilitating hedging instruments, improving access to trade finance during high-volatility periods, and supporting diversification across products and destinations - can complement the gains from trade integration. Maintaining macroeconomic credibility and minimizing unnecessary exchange-rate instability remain important for sustaining long-term competitiveness.

The results do not justify recommending a deliberate policy of real depreciation (or appreciation) as a general export-promotion tool. Instead, the evidence supports prioritizing macroeconomic stability and avoiding prolonged real appreciation driven by inflation differentials rather than productivity gains, while enhancing competitiveness through structural measures (productivity, quality upgrading, logistics, and diversification). Given the asymmetric REER responses in NARDL, the export payoff from REER movements appears state-dependent; policy should therefore focus on limiting excessive misalignments and volatility rather than targeting a particular REER direction.

This study has limitations. Data constraints preclude firm-level customs microdata, and annual frequency may mask short-run adjustment dynamics. The IV strategy relies on external instruments whose strength varies across specifications. Future work could extend the analysis using product-level trade panels (HS-based) and sectoral export data, explore micro-level responses through survey or balance-sheet datasets, and refine identification using higher-frequency instruments and event-study designs around policy and shock episodes.

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Annex 1

Table 30. Summary of robustness check

Robustness dimension	Check / alternative specification	Main result tested	Outcome (summary)	Where shown
ARDL/NARDL specification	Alternative lag orders (AIC/BIC); parsimonious ARDL	Stability of long-run demand and REER effects	Foreign demand effect remains stable; REER weak in linear ARDL but asymmetry persists in NARDL	Tables 22 and 23 [NARDL], [ARDL]
Volatility measurement	Alternative GARCH-family volatility (GARCH/EGARCH/TGARCH)	Stability of volatility proxy	Volatility series exhibits comparable dynamics; annualized measure robust to model choice	Tables 1, 2 and 3 [GARCH], [EGARCH/TGARCH]
IV identification	Alternative instrument: ECB DFR (baseline) vs VIX (robustness)	Endogeneity of volatility and sign of volatility effect	ECB-IV: moderate relevance + endogeneity detected; negative (marginal) volatility effect. VIX-IV: weaker first stage, no endogeneity detected, insignificant volatility effect	Table 15, 16 and 17 [ECB vs VIX IV]
Partner-group definition (PPML)	Add CIS×post2022 interaction	2022 differential by partner group	No robust EU- or CIS-specific break in 2022 beyond year effects; DCFTA-era EU effect stable	Table 13 [EU vs CIS shock]
Partner concentration (PPML)	Split EU destinations: top vs non-top EU partners	Whether DCFTA effect is driven by few partners	Post-2014 EU effect remains positive and similar for top and non-top EU partners (broad-based)	Table 26 [Top vs non-top EU]
Subsample stability	Pre/post 2014 and post-2022 subsamples (where feasible)	Stability around major episodes	EU×post2014 remains positive and significant when restricting the sample to 2000–2024 or 2005–2024; EU×post2022 remains insignificant.	Table 9 [Alt start-year PPML]

Sources: *Author's synthesis based on the robustness checks and econometric estimates reported in the preceding tables. The robustness exercises use annual and bilateral export data from the National Bureau of Statistics of the Republic of Moldova, REER and volatility measures constructed from REER data, EU27 real GDP data from Eurostat, and external instrument data from the European Central Bank and Cboe VIX. Methodological procedures follow the ARDL/NARDL, GARCH-family, PPML, IV/2SLS, and Hansen-type threshold approaches described in the article.*

Note: *The table summarizes the main robustness checks used to assess the stability of the empirical results across alternative model specifications, volatility measures, instruments, partner-group definitions, and subsamples. Detailed estimates are reported in the corresponding tables indicated in the final column.*