

Asymmetric Oil Revenues Fluctuations, Government Budget Deficits, and Exchange Rate Volatility under Sanctions: NARDL–TGARCH Evidence from Iran

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Abstract:

Exchange rate volatility has significant implications for trade, investment, and employment. Consequently, managing exchange rate fluctuations remains a major challenge for economic policymakers, making it essential to identify their underlying determinants. Given the substantial contribution of oil revenues to Iran's export earnings, foreign exchange receipts, and government budget financing, this study investigates the effects of asymmetric oil revenue fluctuations and government budget deficit growth on exchange rate volatility under severe economic sanctions. The analysis employs a combined NARDL–TGARCH framework using quarterly data for the period from 2011: Q4–2021: Q1. The empirical findings indicate that oil revenue fluctuations, government budget deficit growth, and severe economic sanctions have significantly increased exchange rate volatility in both the short run and the long run. The results further reveal that the impact of oil revenue fluctuations is asymmetric in the short run but becomes symmetric in the long run. Moreover, severe sanctions intensify exchange rate volatility by amplifying fluctuations in oil revenues and accelerating government budget deficit growth. Conversely, improvements in government effectiveness and stronger economic growth contribute to reducing exchange rate volatility.

1. Introduction

Exchange rate volatility has significant implications for the macroeconomics, directly affecting the prices of goods and services, trade competitiveness, investment decisions, and employment (Nor, 2015). For firms and manufacturing enterprises, exchange rate uncertainty is particularly important because expectations regarding future exchange rates influence production planning, investment decisions, and profitability (Nor et al., 2020). Consequently,

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understanding the determinants of exchange rate volatility has become a major concern for both policymakers and researchers.

Previous studies have identified several factors influencing exchange rate volatility, including fiscal and monetary policies, oil price shocks, financial market developments, and financial deepening (Li et al., 2016; Liu et al., 2020; Baek, 2021; Khraief et al., 2021; Adi et al., 2022). More recently, economic sanctions have emerged as an important determinant of exchange rate dynamics, particularly in resource-dependent economies. Since the end of World War II, economic sanctions have increasingly been used as a foreign policy instrument to exert political and economic pressure on targeted countries (Giumelli, 2011).

Iran represents one of the most prominent examples of a country that has been subject to extensive international sanctions, particularly after the 1979 Islamic Revolution. These sanctions have intensified over time, with oil-related sanctions becoming especially severe during the past decade (Samore, 2015; Nakhli et al., 2021). Given the strategic importance of Iran's oil and gas sector, Western countries have imposed a series of unilateral and multilateral sanctions targeting oil exports, energy investment, technology transfer, and financial transactions (Lias, 2010; Farzanegan & Dizaji, 2014; Nephew, 2017). According to Barkindo and Al-Qahtani (2019), Iran possesses approximately 155.6 billion barrels of proven crude oil reserves and 33.9 trillion cubic meters of proven natural gas reserves, making it one of the world's largest holders of hydrocarbon resources.

Because oil exports constitute the primary source of foreign exchange earnings and government revenues in Iran, fluctuations in oil revenues have a direct impact on the supply of foreign currency and, consequently, on exchange rate dynamics. Previous studies suggest that changes in oil prices and oil revenue shocks can significantly influence exchange rate movements in oil-exporting countries (Dudlak, 2018). Moreover, severe economic sanctions have substantially reduced Iran's oil exports, thereby lowering oil revenues and widening the government budget deficit (Esfandiary & Fitzpatrick, 2011).

The evolution of sanctions against Iran illustrates the growing pressure on the country's energy sector. The Iran and Libya Sanctions Act (ILSA), enacted in 1996, marked the first comprehensive U.S. sanctions targeting investment in Iran's oil industry (Nakhli et al., 2021). This was followed by the Comprehensive Iran Sanctions, Accountability, and Divestment Act (CISADA) in 2010, which further restricted foreign investment and technology transfer in the oil and gas sector (Esfandiary & Fitzpatrick, 2011). In December 2011, the United States imposed additional financial sanctions on countries importing Iranian crude oil and petrochemical products (Fiedler, 2013; Obama, 2012). Following the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA) in 2018 and the reimposition of sanctions, Iran's crude oil exports declined sharply—from approximately 2.45 million barrels per day to around 1.6 million barrels per day by October 2018 (Trump, 2018; Kerr & Katzman, 2018; Katzman, 2019). These

developments intensified fiscal pressures, increased dependence on monetary financing of budget deficits, and heightened exchange rate instability.

Despite the extensive literature on exchange rate volatility and oil price shocks, relatively little attention has been paid to the asymmetric effects of oil revenue fluctuations and the role of government budget deficits under severe economic sanctions. This study addresses this gap by examining the effects of asymmetric oil revenues fluctuations and government budget deficit growth on exchange rate volatility in Iran under severe sanctions. To capture both asymmetric long-run relationships and time-varying volatility, the study employs a combined NARDL–TGARCH framework using quarterly data spanning the period from 2011: Q4–2021: Q1.

Accordingly, this study seeks to answer the following research questions:

1. Do positive and negative oil revenue fluctuations have asymmetric effects on exchange rate volatility in Iran?
2. Do severe economic sanctions increase exchange rate volatility through their effects on oil revenue fluctuations and government budget deficit growth?

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the theoretical framework, model specification, and methodology. Section 4 discusses the empirical findings. Finally, Section 5 concludes the paper and provides policy implications.

2. Literature Review

Economic, political, and psychological factors all influence exchange rates and their volatility (Hooshmand et al., 2012). Among these factors, the heavy dependence of oil-exporting countries on oil revenues and foreign exchange earnings is considered one of the primary drivers of exchange rate volatility (Adi et al., 2022). In such economies, fluctuations in oil prices or oil revenue shocks significantly affect macroeconomic performance, including exchange rate dynamics (Nikbakht, 2010; Basher et al., 2015; Noura et al., 2018; Dudlak, 2018; Liu et al., 2020; Baek, 2021; Khraief et al., 2021; Adi et al., 2022).

Nikbakht (2010) examined the relationship between oil prices and exchange rates in selected OPEC countries and reported a positive relationship between real oil prices and exchange rates. Using a Markov-switching model, Basher et al. (2015) found that oil supply shocks significantly influence exchange rates in both oil-exporting and oil-importing countries. Similarly, Noura et al. (2018), employing non-causality-in-variance and asymmetric non-causality tests for selected MENA countries (the United Arab Emirates, Tunisia, Qatar, Morocco, Saudi Arabia, and Jordan) over the period from January 2001 to December 2017, concluded that oil price volatility significantly affects exchange rate movements.

Liu et al. (2020) investigated the relationship between crude oil prices and the U.S. dollar exchange rate using a time-varying parameter vector autoregressive

(TVP-VAR) model with quarterly data from 1996 to 2019. Their findings indicate that oil price shocks exert immediate and significant short-run effects on exchange rates. Using the nonlinear autoregressive distributed lag (NARDL) approach, Baek (2021) analyzed the relationship between crude oil prices and exchange rates in selected OPEC member countries, including Algeria, Nigeria, Saudi Arabia, the United Arab Emirates, Venezuela, and Kuwait. The results reveal that the impact of oil prices on real exchange rates depends on the exchange rate regime. Specifically, oil price changes have asymmetric effects on exchange rates in countries with floating exchange rate regimes (Algeria and Nigeria), whereas such asymmetry is not observed in countries operating under fixed exchange rate regimes.

Khraief et al. (2021) also employed the NARDL model to investigate the long-run asymmetric relationship between oil prices and real exchange rates in China and India over the period 1990–2019. They found that oil price shocks have a significant long-run effect on China's exchange rate, whereas their impact on India's real effective exchange rate is relatively weak. Likewise, Adi et al. (2022), using a VAR-AGARCH model and daily data from October 2009 to November 2020, reported that asymmetric oil price shocks significantly influence exchange rate movements.

Beyond oil price shocks, a growing body of literature highlights the role of economic sanctions as an important determinant of exchange rate volatility. Farzanegan and Van Bergeijk (2013) examined the economic costs of the international oil embargo against Iran using a vector autoregression (VAR) model for the period 1995–2012. Their findings indicate that sanctions had severe adverse effects on Iran's macroeconomic performance during the initial years, although their impact gradually diminished as the economy adjusted to the new environment. Similarly, Wang et al. (2019) analyzed the effects of different types of economic sanctions on official exchange rate fluctuations in 23 sanctioned countries between 1996 and 2016 using the least squares dummy variable corrected (LSDVC) estimator. They found that European Union sanctions, bilateral sanctions, and comprehensive sanctions significantly increased exchange rate volatility, whereas U.S. sanctions alone had a relatively limited effect.

Focusing specifically on Iran, Moeini et al. (2020) investigated the impact of oil sanctions on exchange rate fluctuations using the ARDL approach and Google Search Index (GSI) data as a proxy for public expectations. Their results suggest that sanctions influence exchange rates partly through changes in market expectations. Accordingly, reducing international tensions and stabilizing expectations can strengthen the value of the Iranian rial, while prudent monetary policies aimed at controlling liquidity growth can help mitigate exchange rate volatility. Nakhli et al. (2021), using a dynamic stochastic general equilibrium (DSGE) model, demonstrated that oil sanctions reduce foreign investment,

government investment, oil production capacity, and access to extraction technology, while simultaneously increasing the nominal exchange rate.

The literature also emphasizes the close relationship between oil revenues, fiscal balances, and exchange rate dynamics in oil-dependent economies. Farzanegan (2011) argues that when oil revenues decline, the Iranian government is unable to immediately reduce public expenditures, resulting in persistent budget deficits. Similarly, Babak (2013) and Farzanegan and Dizaji (2014) contend that oil sanctions have widened Iran's budget deficit because of the government's heavy dependence on oil revenues. Samimi Jafari and Jamshidbaygi (2011) further show that, under oil sanctions, seigniorage and borrowing from the Central Bank of Iran have become major sources of budget deficit financing. Such monetary financing increases aggregate demand, fuels inflationary pressures, and ultimately contributes to exchange rate volatility (Fatma Turan, 2014). Moreover, several studies suggest the existence of a long-run bidirectional relationship between inflation and exchange rate fluctuations (Olamide et al., 2022). Habibi (2008) argues that currency depreciation raises import costs, thereby increasing both the consumer price index (CPI) and production costs.

Finally, Tayebi and Sadeghi (2017) examined the impact of international sanctions on Iran's exchange rate using the ARDL and error correction models (ECM). Their findings indicate that sanctions imposed before 2012 had only a limited effect on the exchange rate, whereas the intensified sanctions introduced in 2012 had a substantial and statistically significant impact on exchange rate depreciation and volatility.

Overall, the existing literature confirms that oil price shocks, fiscal imbalances, and economic sanctions are among the principal determinants of exchange rate volatility in oil-exporting economies. However, relatively little empirical evidence exists regarding the asymmetric effects of oil revenue fluctuations on exchange rate volatility under severe sanctions while simultaneously accounting for government budget deficit growth. This study seeks to fill this gap by employing a combined NARDL–TGARCH framework to investigate these relationships in the case of Iran.

3. Econometric Model and Data Set

The autoregressive conditional heteroskedasticity (ARCH) model was originally proposed by Engle (1982) to model time-varying conditional variance. Its principal advantage is its ability to capture volatility clustering in financial and macroeconomic time series. Bollerslev (1986) subsequently generalized the ARCH framework by introducing the generalized ARCH (GARCH) model, which allows the conditional variance to depend on both past squared disturbances and past conditional variances.

A key limitation of the standard GARCH model is its assumption that positive and negative shocks have symmetric effects on volatility. In practice, however, economic and financial variables often exhibit asymmetric responses to shocks. To address this limitation, Nelson (1991) proposed the Exponential GARCH (EGARCH) model, while Zakoian (1994) introduced the Threshold GARCH (TGARCH) model, both of which explicitly account for asymmetric volatility effects. The TGARCH specification can be expressed as follows:

$$\begin{aligned}\sigma_t^2 &= \omega + \alpha \varepsilon_{t-1} + \gamma \varepsilon_{t-1}^2 d_{t-1} + \beta \sigma_{t-1}^2 \\ d_{t-1} &= \begin{cases} 1 & \text{if } \varepsilon_{t-1} < 0 \\ 0 & \text{if } \varepsilon_{t-1} > 0 \end{cases}\end{aligned}\quad (1)$$

Where ε denotes the white-noise error term. In this specification, positive shocks affect conditional volatility through the coefficient α , whereas negative shocks affect volatility through $\alpha + \gamma$. Therefore, if the coefficient γ is statistically different from zero, positive and negative shocks of equal magnitude exert asymmetric effects on volatility.

The primary objective of this study is to examine the effects of asymmetric oil revenue fluctuations and government budget deficit growth on exchange rate volatility under severe economic sanctions in Iran. To this end, a combined NARDL–TGARCH framework is employed using **quarterly data** covering the period 2011:Q4–2021:Q1. To capture both short-run and long-run asymmetries, this study adopts the nonlinear autoregressive distributed lag (NARDL) model developed by Shin et al. (2014). The general specification is given as follows:

$$\begin{aligned}ERV_t &= \alpha_0 + \sum_{i=1}^p \rho_i ERV_{t-i} + \sum_{j=0}^q (\theta_j^+ ORV_{t-j}^+ + \theta_j^- ORV_{t-j}^-) + \sum_{j=0}^r \delta_j BD_{t-j} + \sum_{j=0}^s \lambda_j BD_{t-j} \cdot SANC \\ &\quad + \sum_{j=0}^v \gamma_j ORV_{t-j} \cdot SANC + \sum_{j=0}^w \gamma_j GGDP_{t-j} + \sum_{j=0}^z \mu_j GOV_{t-j} + \delta SANC + e_t\end{aligned}\quad (2)$$

Where (ERV) denotes exchange rate volatility, (ORV) represents oil revenue fluctuations, (BD) denotes government budget deficit growth, (GGDP) is the economic growth rate (measured at constant 2011 prices), and (GOV) represents government effectiveness. The variable **SANC** is a dummy variable capturing periods of severe economic sanctions. It takes the value of one for the periods from **2012 to 2015** and from **2018 to 2021**, and zero otherwise. These periods correspond to the intensified sanctions imposed in 2012 and the reimposition of comprehensive sanctions following the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA) in 2018.

The coefficients (ORV^+) and (ORV^-) capture the short-run asymmetric effects of positive and negative oil revenue changes, respectively. The corresponding nonlinear error-correction representation of the NARDL model is specified as follows:

$$\begin{aligned}
\Delta ERV_t = & \alpha_0 + \rho ERV_{t-1} + \beta_1^+ ORV_{t-1}^+ + \beta_1^- ORV_{t-1}^- + \beta_2 BD_{t-1} + \beta_3 GGDP_{t-1} + \beta_4 ORV_{t-1} \cdot SANC + \beta_5 BD_{t-1} \cdot SANC \\
& + \sum_{i=1}^p \gamma_i \Delta ERV_{t-i} + \sum_{j=0}^q (\theta_j^+ \Delta ORV_{t-j}^+ + \theta_j^- \Delta ORV_{t-j}^-) + \sum_{j=0}^r \lambda_j \Delta BD_{t-j} + \sum_{j=0}^s \eta_j \Delta BD_{t-j} \cdot SANC + \sum_{j=0}^v \gamma_j ORV_{t-j} \cdot SANC \\
& + \sum_{j=0}^w \mu_j \Delta GGDP_{t-j} + \sum_{j=0}^z \mu_j GOV_{t-j} + \delta SANC + \tau ECT_{t-1} + e_t
\end{aligned} \quad (3)$$

The coefficient of the error correction term, (ECT_{t-1}), is expected to be negative and statistically significant, indicating convergence toward the long-run equilibrium following short-run deviations. The optimal lag length is selected using the Akaike Information Criterion (AIC).

$\phi_1 = -\beta_1^+ / \rho$ and $\phi_2 = -\beta_1^- / \rho$ represent the long-run asymmetric effects of positive and negative oil revenue fluctuations, respectively. The existence of a long-run cointegration relationship among exchange rate volatility, oil revenue fluctuations, government budget deficit growth, economic growth, and government effectiveness is examined using the bounds-testing approach proposed by Pesaran et al. (2001). To evaluate whether positive and negative changes in oil revenues have statistically different effects, the Wald test is employed to test both long-run and short-run symmetry restrictions. Rejection of the null hypothesis indicates the presence of asymmetric effects.

$$ORV_t = ORV_0 + ORV_t^+ + ORV_t^- \quad (4)$$

$$ORV_t^+ = \sum_{j=1}^t \Delta ORV_j^+ = \text{Max}(\Delta ORV_j, 0) \quad (5)$$

$$ORV_t^- = \sum_{j=1}^t \Delta ORV_j^- = \text{Min}(\Delta ORV_j, 0) \quad (6)$$

If the null hypothesis of long-run symmetry cannot be rejected, Equation (3) simplifies to a restricted NARDL specification that permits only short-run asymmetry:

$$\begin{aligned}
\Delta ERV_t = & \alpha_0 + \rho ERV_{t-1} + \beta_1 ORV_{t-1} + \beta_2 BD_{t-1} + \beta_3 GGDP_{t-1} + \beta_4 BD_{t-1} \cdot SANC + \beta_5 ORV_{t-1} \cdot SANC + \sum_{i=1}^p \gamma_i \Delta ERV_{t-i} \\
& + \sum_{j=0}^q (\theta_j^+ \Delta ORV_{t-j}^+ + \theta_j^- \Delta ORV_{t-j}^-) + \sum_{j=0}^r \lambda_j \Delta BD_{t-j} + \sum_{j=0}^s \eta_j \Delta BD_{t-j} \cdot SANC + \sum_{j=0}^v \gamma_j ORV_{t-j} \cdot SANC + \sum_{j=0}^w \mu_j \Delta GGDP_{t-j} \\
& + \sum_{j=0}^z \mu_j GOV_{t-j} + \delta SANC + \tau ECT_{t-1} + e_t
\end{aligned} \quad (6)$$

4. Empirical Findings and Discussion

4.1. ARCH Effect Test

This study examines the effects of asymmetric oil revenue fluctuations and government budget deficit growth on exchange rate volatility under severe economic sanctions in Iran. The analysis employs a combined NARDL–TGARCH framework using quarterly data covering the period from 2011: Q4–2021: Q1.

Before estimating the volatility model, it is necessary to examine the time-series properties of the variables. Since the ARCH-family models require stationary series, the seasonal stationarity of the variables is first tested using the HEGY seasonal unit root test. The results are reported in **Table 1**.

Table 1. HEGY Seasonal Unit Root Test Results

Variables	Null hypothesis	t-statistic	P-value
OR	Non-seasonal unit root (zero frequency)	0.57	0.999
	Seasonal unit root (two quarters per cycle)	-9.27	0.000
	Seasonal unit root (four quarters per cycle)	70.94	0.000
ER	Non-seasonal unit root (zero frequency)	-1.45	0.861
	Seasonal unit root (two quarters per cycle)	-6.27	0.000
	Seasonal unit root (four quarters per cycle)	27.65	0.000

Note: The HEGY test examines the presence of seasonal unit roots at zero frequency, two quarters per cycle, and four quarters per cycle.

Source: Authors' calculations.

Following the stationary analysis, the conditional mean equations were specified by identifying the optimal ARIMA and SARIMA models. Based on the Akaike Information Criterion (AIC), an **AR (1)-MA (4)** model was selected for the logarithm of the exchange rate, whereas an **AR (1)-MA (12)-SMA (4)** specification was selected for the logarithm of oil revenues.

After estimating the conditional mean equations, diagnostic tests were performed on the residuals to determine whether conditional heteroskedasticity was present. The ARCH-LM test results indicate significant ARCH effects in both the exchange rate and oil revenue series, suggesting that the variance of the residuals is not constant over time. Consequently, volatility models from the ARCH/GARCH family are appropriate for modeling the conditional variance of these variables.

The results of the ARCH-LM test are presented in **Table 2**.

Table 2. ARCH-LM Test Results

Test Statistic	Logarithm of Exchange Rate	Logarithm of Oil Revenues
F-statistic	9.20 (0.002)**	30.09 (0.000)***
Chi-square	8.81 (0.003)**	25.64 (0.000)***

Note: ***, ** denote statistical significance at the 1% and 5% levels, respectively. The values in parentheses are the corresponding *p*-values.

Source: Research Finding

The null hypothesis of homoscedastic residuals is rejected for both variables according to the F-statistic and Chi-square statistic. These findings provide strong evidence of conditional heteroskedasticity, confirming that exchange rates and oil revenues exhibit time-varying volatility. Therefore, the application of the TGARCH model is appropriate, as it allows for the estimation of conditional

variance while accounting for potential asymmetric responses of volatility to positive and negative shocks.

The conditional variance series estimated using the TGARCH model indicate the presence of asymmetric volatility in both the logarithm of the exchange rate and the logarithm of oil revenues. For the logarithm of the exchange rate, the estimated asymmetry coefficient is **negative** ($\gamma < 0$).e, exchange rate volatility in Iran responds more strongly to positive shocks than to negative shocks.

In contrast, for the logarithm of oil revenues, the estimated asymmetry coefficient is **positive** ($\gamma > 0$). This implies that **negative shocks exert a larger effect on oil revenue volatility than positive shocks of equal magnitude**, suggesting that declines in oil revenues generate greater volatility than comparable increases. This finding is particularly relevant for an oil-dependent economy such as Iran, where adverse oil revenue shocks have substantial macroeconomic consequences. These results are consistent with the findings of Bebonchu et al. (2015) and Ahmad and Hernandez (2013).

Figures 1 and 2 present the estimated conditional variance series for the logarithms of oil revenues and the exchange rate, respectively, illustrating the time-varying volatility captured by the TGARCH model.

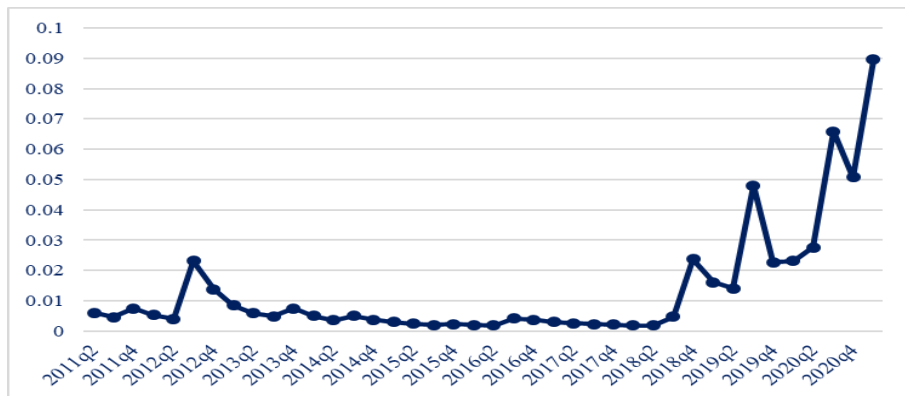


Figure 1. Estimated Conditional Variance of the Logarithm of Oil Revenues in Iran Based on the TGARCH Model

Source: Research Finding

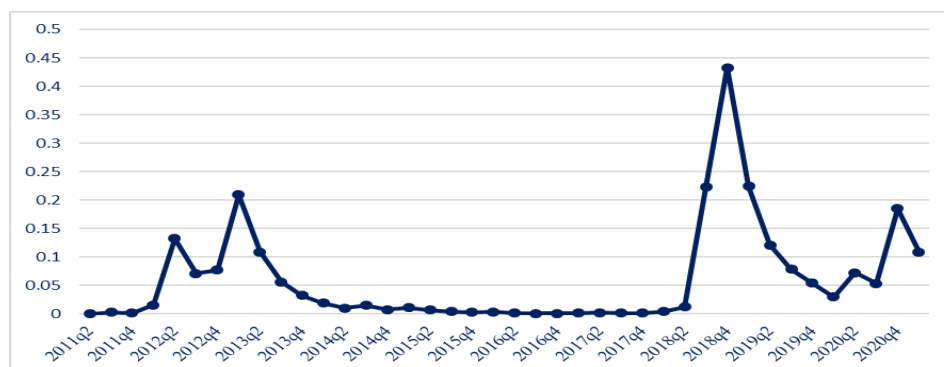


Figure 2. Estimated Conditional Variance of the Logarithm of Exchange Rate in Iran Based on the TGARCH Model.

Source: Research Finding

4.2. Estimation Results

The NARDL approach can be applied when the variables are integrated of order zero, $I(0)$, or order one, $I(1)$; however, it is not applicable when any variable is integrated of order two, $I(2)$. Therefore, before employing the ARDL/NARDL methodology, it is necessary to examine the stationarity properties of all variables. To this end, the seasonal unit root test proposed by HEGY is conducted, and the results are presented in Table 3.

Table 3. HEGY Seasonal Unit Root Test Results

Variables	Null hypothesis	t-statistic	P-value
EXOV	Non-seasonal unit root (zero frequency)	-5.53	0.010
	Seasonal unit root (two quarters per cycle)	-6.99	0.010
	Seasonal unit root (four quarters per cycle)	52.43	0.000
BD	Non-seasonal unit root (zero frequency)	-3.25	0.090
	Seasonal unit root (two quarters per cycle)	-3.76	0.020
	Seasonal unit root (four quarters per cycle)	19.71	0.000
GGDP	Non-seasonal unit root (zero frequency)	-1.22	0.890
	Seasonal unit root (two quarters per cycle)	-6.71	0.010
	Seasonal unit root (four quarters per cycle)	23.46	0.000
GOV	Non-seasonal unit root (zero frequency)	-2.23	0.460
	Seasonal unit root (two quarters per cycle)	-3.71	0.010
	Seasonal unit root (four quarters per cycle)	20.66	0.000
ERV	Non-seasonal unit root (zero frequency)	-4.16	0.010
	Seasonal unit root (two quarters per cycle)	-6.34	0.010
	Seasonal unit root (four quarters per cycle)	32.68	0.000

Note: The HEGY seasonal unit root test examines unit roots at zero frequency, two quarters per cycle, and four quarters per cycle.

Source: Research Finding

The results of the HEGY seasonal unit root test reported in Table 3 indicate that none of the variables are integrated of order two, $I(2)$. The variables are found to be either stationary at level, $I(0)$, or become stationary after first differencing,

I(1). Therefore, the precondition for applying the ARDL/NARDL methodology is satisfied, and the model can be appropriately estimated.

The result of ARDL Bounds test for Cointegration relationship among the variables reported in table 4.

Table 4. Bounds Test for Cointegration relationship among the variables

F-Statistic	Critical Value		Result
4.79	Lower Bound I(0)	Upper Bound I(1)	Long-run relationship
	2.96 (%1)	4.26 (%1)	

Note: The computed F Statistic is equal 4.79 that greater than the critical value at 1% significance level. The critical values for the Bounds test are obtained from Pesaran et al. (2001). Since the calculated F-statistic is greater than both the lower and upper bound values, the null hypothesis of no cointegration is rejected, confirming the existence of a long-run relationship among the variables.

Source: Research Finding

The ARDL Bounds test results indicate that the calculated F-statistic (4.79) is higher than the upper bound critical value (4.26) at the 1% significance level. Therefore, the null hypothesis of no long-run relationship among the variables is rejected. These findings provide evidence of a stable long-run cointegration relationship among the variables, supporting the application of the ARDL approach for estimating both short-run and long-run effects. The estimated short-run and long-run coefficients obtained from the NARDL–TGARCH model for the period 2011: Q4–2021: Q1 are reported in Tables 5 and 6, respectively. The optimal lag length was selected using the Schwarz Information Criterion (SIC). The results of the Wald test indicate that oil revenue fluctuations have an asymmetric effect on exchange rate volatility in the short run, whereas this relationship becomes symmetric in the long run.

Table 5. Short-run Estimation Results of the NARDL–TGARCH Model

Variables	Coefficient	t-Statistics
$\Delta EXOV^+$	1.814**	2.06
$\Delta EXOV^-$	1.761***	2.68
ΔBD	0.197**	2.08
$\Delta GGDP$	$-1.21 e^{-6}$ ***	-2.82
ΔGOV	0.162	0.85
$\Delta SANC$	0.135***	5.05
$\Delta(EXOV \times SANC)$	3.257***	3.51
$\Delta(BD \times SANC)$	0.209**	2.39
$ECM (-1)$	-1.072***	-7.72
Diagnostic Tests	Statistic	Result
LM Test	1.81	No serial correlation
RESET Test	1.88	Model correctly specified
ARCH-test	0.13	Homoscedastic residuals
Wald-S Test	4.34**	Short-run asymmetry confirmed

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Research Finding

Table 6. Long-run Estimation Results of the NARDL–TGARCH Model

Variables	Coefficient	t-Statistics
$\Delta EXOV^+$	1.693**	2.03
$\Delta EXOV^-$	1.644***	2.92
BD	0.184**	2.46
GGDP	-1.132***	-2.66
GOV	-0.495***	-4.71
SANC	0.126***	5.30
$EXOV \times SANC$	3.039***	3.30
$BD \times SANC$	0.195**	2.25
Constant	0.064***	3.95
Asymmetry Test		
Wald-L	0.608	Long-run symmetry not rejected

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The optimal lag length is selected using the Schwarz Information Criterion (SIC).

Source: Research Finding

The short-run estimation results show that the coefficients of **positive and negative oil revenue fluctuations ($EXOV^+$ and $EXOV^-$)** are **1.814** and **1.761**, respectively, and are statistically significant at the 5% and 1% significance levels. Similarly, the long-run results indicate that the corresponding coefficients are **1.693** and **1.644**, respectively, and remain statistically significant. These findings suggest that changes in oil revenues exert a significant influence on exchange rate volatility in both the short and long run. The results are consistent with those reported by Nikbakht (2010), Basher et al. (2015), Nour et al. (2018), Dudlak (2018), Liu et al. (2020), Baek (2021), Khraief et al. (2021), and Adi et al. (2022). The estimated coefficients of the severe sanctions variable are **0.135** in the short run and **0.126** in the long run, both of which are statistically significant at the 1% level. These results indicate that severe sanctions have significantly increased exchange rate volatility over both time horizons. Furthermore, the interaction term between severe sanctions and oil revenue fluctuations ($EXOV \times SANC$) has coefficients of **3.257** and **3.039** in the short and long run, respectively, and both are statistically significant at the 1% level. These findings imply that the impact of sanctions on exchange rate volatility operates primarily through the oil revenue channel, highlighting the high dependence of Iran's economy on volatile oil revenues. The reduction in oil export revenues caused by sanctions has intensified exchange rate instability and, consequently, increased overall macroeconomic uncertainty. These findings are consistent with the evidence reported by Wang et al. (2019), Moeini et al. (2020), and Nakhli et al. (2021), who show that oil-related sanctions and financial restrictions have substantially increased exchange rate instability in Iran.

The interaction term between severe sanctions and government budget deficit growth ($BD \times SANC$) is estimated at **0.197** in the short run and **0.184** in the long

run, with both coefficients being statistically significant at the 5% level. This finding indicates that severe sanctions have also increased exchange rate volatility by exacerbating the government's budget deficit. As oil revenues declined under sanctions, fiscal imbalances widened, creating additional pressure on the foreign exchange market and increasing exchange rate volatility. This result is in line with the findings of Samimi Jafari and Jamshidbaygi (2011), Babak (2013), Faraji Dizaji (2014), and Tayebi and Sadeghi (2017).

Real GDP growth (measured at constant 2013 prices) has a negative and statistically significant effect on exchange rate volatility in both the short and long run, with a stronger effect observed in the long run. This finding suggests that higher economic growth contributes to exchange rate stability by strengthening macroeconomic fundamentals, improving export performance, and reducing pressures in the foreign exchange market.

Government effectiveness does not have a statistically significant effect on exchange rate volatility in the short run. However, its long-run coefficient is -0.495 and statistically significant at the 1% level, indicating that improvements in governance reduce exchange rate volatility over time. This finding underscores the importance of efficient public resource management, sound economic policies, and strong institutional quality in promoting exchange rate stability.

Finally, several diagnostic tests were conducted to evaluate the adequacy of the estimated model. The LM test confirms the absence of serial correlation in the residuals, while Ramsey's RESET test indicates that the model is correctly specified. Moreover, the Wald-S test confirms the presence of short-run asymmetry in the effects of oil revenue fluctuations on exchange rate volatility, whereas the Wald-L test fails to reject the null hypothesis of long-run symmetry. The ARCH-LM test fails to reject the null hypothesis of no ARCH effects. Therefore, there is no evidence of remaining conditional heteroskedasticity in the residuals, indicating that the estimated model has adequately captured the volatility dynamics.

5. Conclusions and policy implications

Given the specific conditions of Iran's economy and the intensification of severe sanctions in recent years, addressing the sources of economic uncertainty, particularly exchange rate volatility, and identifying the factors contributing to its formation are among the most important economic policy challenges. Therefore, this study investigates the effects of asymmetric fluctuations in oil revenues and government budget deficit growth on exchange rate volatility under severe sanctions in Iran using the NARDL-TGARCH approach over the period 2011: Q4-2021: Q1.

To model exchange rate and oil revenue volatility using the ARCH framework, the stationary properties of the variables were examined. The ARCH effect test for the logarithmic series of the exchange rate and oil revenues confirms the

existence of conditional heteroskedasticity in the residuals of the return series. The results of the TGARCH model indicate that the conditional variance specifications provide the best estimation of volatility for both the logarithmic exchange rate and oil revenue series. Furthermore, for the logarithmic exchange rate series, the impact of negative shocks on exchange rate volatility is lower than that of positive shocks. In contrast, for the logarithmic oil revenue series, negative shocks have a stronger effect on oil revenue fluctuations than positive shocks in Iran.

The findings reveal that oil revenue fluctuations have an asymmetric effect on exchange rate volatility in the short run, whereas this relationship becomes symmetric in the long run. The results also demonstrate that severe sanctions have increased exchange rate volatility through the channels of oil revenue fluctuations and government budget deficit growth. Among these channels, the impact of sanctions through oil revenue fluctuations has been the most significant, highlighting the high dependence of Iran's economy on oil revenues. Therefore, severe sanctions, both directly and indirectly through fluctuations in oil revenues and increases in the government budget deficit, have contributed to higher exchange rate volatility in both the short and long run.

The results further indicate that real GDP growth (at constant 2013 prices) reduces exchange rate volatility in both the short and long run, with a stronger effect in the long run. In addition, government efficiency has a negative effect on exchange rate volatility, suggesting that effective economic management, efficient resource allocation, and institutional quality play an important role in stabilizing the foreign exchange market.

The Foreign Exchange Reserve Account and the National Development Fund were established to mitigate the transmission of oil revenue fluctuations to the domestic economy and to provide financial resources for crisis periods and future generations. Based on the findings of this study, the following policy recommendations are proposed:

- Strengthening monitoring and improving the performance of the National Development Fund to ensure that foreign exchange revenues from oil exports are effectively utilized to reduce exchange rate fluctuations.
- Implementing reforms in the trade structure and tax system to reduce Iran's economic dependence on oil revenues and minimize the vulnerability caused by oil revenue fluctuations.
- Increasing the saving and investment of a portion of foreign exchange resources generated from oil revenues, particularly during periods of severe sanctions, in order to enhance economic resilience and reduce exchange rate instability.

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نوسانات نامتقارن درآمدهای نفتی، کسری بودجه دولت و نوسانات نرخ ارز تحت تحریم‌ها: شواهدی از NARDL-TGARCH در ایران

چکیده

نوسانات نرخ ارز آثار قابل توجهی بر تجارت، سرمایه‌گذاری و اشتغال دارد. از این رو، مدیریت نوسانات نرخ ارز همواره یکی از مهم‌ترین چالش‌های سیاست‌گذاران اقتصادی بوده و شناسایی عوامل تعیین‌کننده آن از اهمیت ویژه‌ای برخوردار است. با توجه به نقش اساسی درآمدهای نفتی در درآمدهای صادراتی، درآمدهای ارزی و تأمین مالی بودجه دولت در ایران، این پژوهش به بررسی اثر نوسانات نامتقارن درآمدهای نفتی و رشد کسری بودجه دولت بر نوسانات نرخ ارز در شرایط تحریم‌های شدید اقتصادی می‌پردازد. برای این منظور، از چارچوب ترکیبی NARDL-TGARCH و داده‌های فصلی دوره **سه‌ماهه سال ۲۰۱۱ تا سه‌ماهه اول سال ۲۰۲۱** استفاده شده است. یافته‌های تجربی نشان می‌دهد که نوسانات درآمدهای نفتی، رشد کسری بودجه دولت و تحریم‌های شدید اقتصادی، نوسانات نرخ ارز را در هر دو افق کوتاه‌مدت و بلندمدت به‌طور معناداری افزایش داده‌اند. همچنین، نتایج بیانگر آن است که اثر نوسانات درآمدهای نفتی در کوتاه‌مدت نامتقارن، اما در بلندمدت متقارن است. افزون بر این، تحریم‌های شدید از طریق تشدید نوسانات درآمدهای نفتی و تسریع رشد کسری بودجه دولت، موجب افزایش نوسانات نرخ ارز می‌شوند. در مقابل، بهبود اثربخشی دولت و تقویت رشد اقتصادی به کاهش نوسانات نرخ ارز کمک می‌کند.

واژه‌های کلیدی: نوسانات نرخ ارز؛ نوسانات درآمدهای نفتی؛ کسری بودجه دولت؛ تحریم‌های اقتصادی؛ NARDL؛ TGARCH؛ ایران.

طبقه‌بندی JEL: C50, H60, F51, F44, F31.