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Beyond traditional defenses: Unraveling the dynamics of reserves and exchange rate volatility in the face of economic sanctions

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Abstract

This study investigates the impact of economic sanctions on exchange rate volatility, with a specific focus on the role of foreign reserves in mitigating these effects across 21 countries from 2002 to 2022. Employing advanced econometric models, including Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS), our analysis identifies a positive correlation between economic sanctions and increased exchange rate volatility. A significant finding is that high reserves-to-GDP ratios do not fully stabilize exchange rate volatility in the presence of economic sanctions, challenging the traditional view of reserves as reliable stabilizers. It also demonstrates an inverse relationship between heightened reserves-to-GDP ratios and economic growth during periods of sanctions, indicating that larger reserves may reflect economic difficulties rather than strength. These findings implicitly call for a reevaluation of economic policies in favor of adopting strategies that mitigate global economic uncertainties. Supported by previous literature, the importance of international cooperation and governance that foster economic and trade diversification is highlighted. This approach can provide alternative sources of foreign exchange and reduce economic vulnerability to sanctions, enhancing overall economic resilience and stability.

Keywords: economic sanctions, exchange rate volatility, total reserves, geopolitical risks.
JEL classification: F31, F34, F51, P45.

1. Introduction

The global economic landscape is continuously influenced by various factors, including economic sanctions, which have emerged as powerful tools with far-

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reaching implications. Often employed for political or diplomatic reasons, sanctions can significantly impact the economies of both sanctioning and sanctioned nations. This study focuses on the interaction between economic sanctions, national reserves, and exchange rate volatility. Covering two decades and encompassing data from 21 countries, the research aims to illuminate the real impact of sanctions on exchange rate volatility and the effectiveness of national reserves as a protective mechanism. Advanced methodologies, such as Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS), offer a nuanced and comprehensive analysis of these interactions. This research contributes to a deeper understanding of economic resilience in the face of sanctions and informs the development of effective economic strategies and policies in today's interconnected global economy.

The paper reviews the effectiveness of economic sanctions as foreign policy tools. Abbott (1987) highlighted their symbolic and communicative aspects, while Drury (1998) analyzed their effectiveness. Kim (2009) pointed out variables like the sender state's democracy affecting sanction success. Shahadat Hossain Siddiquee and van Bergeijk (2012) noted biases in sanctions data. Knobel et al. (2019) suggested proactive policies like market openness over retaliation. Felbermayr et al. (2021) recommended interdisciplinary approaches for a comprehensive view of sanctions and their impact on exchange rate volatility.

Morina et al. (2020) found a negative correlation of exchange rate volatility with economic growth in Central and Eastern Europe. Khaliq (2022) observed that domestic risks influenced Indonesia's rupiah–dollar volatility more than global risks. Salisu et al. (2022) noted that BRICS nations' exchange rates were sensitive to global risks, including sanctions. Research shows that sanctions significantly affect exchange rates, as seen in Iran's gold market (Mashayekhi et al., 2013) and the ruble's oil price sensitivity in Russia (Aganin and Peresetsky, 2018). Wang et al. (2019) found consistent exchange rate influences due to sanctions across 23 countries.

Foreign exchange reserves are critical in stabilizing currency and reducing volatility, particularly in emerging markets. Hviding et al. (2004) analyzed data from 28 countries between 1986 and 2002 and found that substantial reserves can protect against exchange rate fluctuations. Cady and Gonzalez-Garcia (2007) explored the impact of transparency in reserve declaration, specifically adherence to the IMF's International Reserves and Foreign Currency Liquidity Data Template. Their findings suggest that such transparency can decrease exchange rate volatility by up to 20%. Hakim (2013) provided a more nuanced view, focusing on the reserves-to-import ratio (TRM) as a measure of reserve adequacy.

The relationship between international reserves and economic stability, especially in the context of economic sanctions, represents a multifaceted field of inquiry. Gordon and Leeper (1994) dispute the traditional interpretations of monetary policy shocks, positing that fluctuations in reserves are not always indicative of policy shifts. Ocampo (2007) critiques the international reserve system, underscoring its role in exacerbating economic volatility and global disparities. Furthermore, Vinokurov et al. (2020) uncover that the debt-to-GDP threshold differs according to the institutional quality of a country; less developed nations have a threshold of around 37%, while it escalates to above 55% in countries with

stronger institutions, reflecting a greater tolerance for debt in more developed economies. These investigations collectively highlight the complex relationship between reserves, sanctions, and exchange rate fluctuations.

To further contextualize the economic resilience against sanctions and economic volatilities, the role of the Global Financial Safety Net (GFSN) becomes increasingly pertinent. The GFSN, with its expanding role of Multilateral Development Banks (MDBs) and bilateral financing, offers crucial support to countries grappling with budget constraints and balance-of-payment crises. Vinokurov and Levenkov (2021) emphasize the GFSN's rapidly rising role in enhancing global financial stability, marking a significant shift towards collaborative international efforts to mitigate economic shocks.

2. The current study

Our study explores the complex interplay between economic sanctions, total reserves, and exchange rate volatility in 21 countries from 2002 to 2022, filling a significant gap in the current economic literature. Previous works, such as those by Hviding et al. (2004), Cady and Gonzalez-Garcia (2007), and Tavares (2015), predominantly regard reserves as buffers against volatility. Our findings diverge from these conventional theories, suggesting that in environments burdened with sanctions, augmented reserves do not consistently correlate with reduced volatility, challenging the traditional role of reserves as stabilizing agents. Addressing a notable gap, the research delves into the nuances of the reserve-to-GDP ratio. Contrary to the general belief, it posits that an elevated reserve-to-GDP ratio under sanctions might not signify genuine reserve accumulation but could instead reflect an economic contraction. This critical insight prompts a reevaluation of the traditional metrics used to assess economic resilience in nations experiencing sanctions. Furthermore, the study identifies and underscores the tangible constraints faced by sanctioned nations, such as asset freezes and access limitations. These constraints, often overlooked in existing literature, can severely undermine the effectiveness of reserves, adding complexity to their role in safeguarding against economic instability.

Methodologically, the study employs two sophisticated statistical models: Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS). The PCSE method addresses cross-sectional dependence and heteroskedasticity issues, while FGLS effectively handles panel-specific challenges and potential endogeneity. The combined use of these models enhances the robustness and comprehensiveness of the analysis, solidifying the validity of our findings.

The study is structured to test several hypotheses: H1 posits that economic sanctions significantly increase exchange rate volatility; H2 asserts that a higher reserves-to-GDP ratio is associated with reduced volatility; H3 suggests that in the context of economic sanctions, high reserves relative to GDP do not fully stabilize exchange rate volatility; and H4 indicates an inverse relationship between the reserve-to-GDP ratio and economic growth in countries under sanctions.

The remainder of the paper is organized as follows: Section 3 delves into the methodology and data overview; Section 4 conducts the empirical analysis and shares the results; Section 5 engages in discussions, while Section 6 wraps up with conclusions and policy suggestions.

3. Data and methodology

3.1. Data

3.1.1. Data source

Our study conducts an in-depth examination of data from 21 countries frequently targeted by sanctions, analyzing the distribution and principal entities responsible for these measures, which is illustrated in Fig. 1. The research utilizes two key data sources: The World Bank's World Development Indicators System (WDIS) and the Global Sanctions Data Base (GSDB; see Felbermayr et al., 2020; Kirilakha et al., 2021; Syropoulos et al., 2022). The detailed sources of the data employed in this study are listed in Table 1.

3.1.2. Variables

3.1.2.1. Dependent variable

This study utilizes historical volatility as a substitute to examine the complex notion of exchange rate volatility, following the methodology described by Ichiue and Koyama (2011). To obtain a more localized measure of volatility, we account for the fluctuations of the U.S. dollar (USD), which has a substantial influence on global exchange rates. This method separates the inherent instability of other currencies from the impacts of fluctuations in the USD. The study employs a standardized metric to reduce distortions resulting from major fluctuations in the value of the USD. The process of normalization, which has been supported by Chile et al. (2021) and Avramov and Xu (2019), is computed as follows:

$$\Delta Adj\,ER_t = (\Delta ER_t - \Delta USDI_t) / |\Delta USDI_t|, \tag{1}$$

where $\Delta Adj\,ER_t$ is the adjusted relative change in the exchange rate at time t; ΔER_t is the relative change in exchange rate, calculated as $(ER_t - ER_{t-1})/ER_{t-1}$; $\Delta USDI_t$ is the relative change in the U.S. dollar index, calculated as $(USDI_t - USDI_{t-1})/USDI_{t-1}$.

This adjusted measure is crucial for understanding the impact of foreign interest rates on currency returns and exchange rate changes, a point emphasized by Avramov and Xu (2019). We use the standard deviation of monthly real-exchange-rate data, consistent with methodologies from Yakubu et al. (2022), Zhang et al. (2008), and Aktaş et al. (2014). The standard deviation, a recognized measure of volatility (Vol), as shown in Equation 2, effectively captures the unpredictability in currency markets, as noted by Errais and Bahri (2016).

$$Vol_t = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(ER_i - \overline{ER})^2}, \tag{2}$$

where Vol_t is the volatility of the exchange rate at time t; N is the number of observations in the month; ER_i is the exchange rate at observation i; $\overline{ER}$ is the average exchange rate for the month.

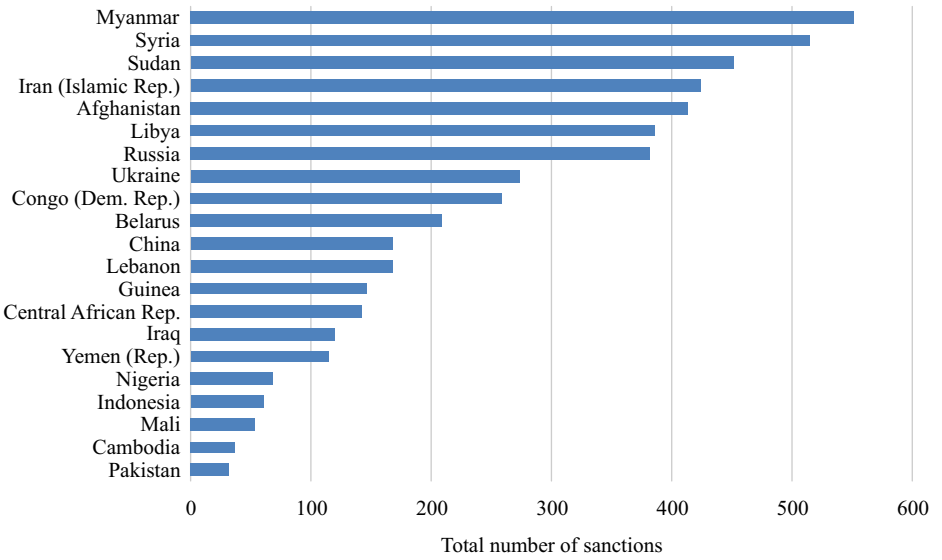

Fig. 1. Distribution of sanctions among sampled countries.

Source: Authors' calculations.

Table 1
Variable definitions and data sources.

Variable	Definition	Source
Exchange rate	Official exchange rate (local currency units per USD, monthly average)	World Development Indicators (WDI)
Presence	Binary economic sanction exposure	GSDB (Felbermayr et al., 2020; Kirilakha et al., 2021; Syropoulos et al., 2022); Office of Foreign Assets Control (OFAC); Common Foreign and Security Policy (CFSP) of the European Union; Australia Consolidated List; European Union Restrictions on Access to the Capital Market; UK Office of Financial Sanctions Implementation, HM Treasury
Frequency	Annual economic sanction frequency (eco frequency)	
Intensity	Economic and non-economic sanction source intensity (reflects the count of economic and non-economic sanctions from various senders— USA, EU, UN, Others, and Multiple— with "Multiple" indicating instances where more than one "Others" sender is involved)	
Severity	Economic and non-economic comprehensive sanction severity, weight emphasis on trade-related and financial sanctions	
Duration	Economic sanction cumulative duration	
Reserves	Total reserves includes gold (% of GDP)	WDI; International Monetary Fund (IMF); International Financial Statistics (IFS)
Growth	GDP growth (annual %) real— constant at 2010 USD	WDI
Inflation	Inflation, consumer prices (annual, %)	
Interest	Lending interest rate (%)	
Current	Current account balance (% of GDP)	
Political	Political stability and absence of violence/ terrorism: Estimate	

Note: Economic sanction includes trade export, trade import, and financial; Non-economic sanction: arms, military, travel, other.
Source: Compiled by the authors.

3.1.2.2. Sanctions variables

This paper examines the impact of economic sanctions on exchange rate volatility, focusing on five critical explanatory variables: binary economic sanction presence (*Presence*), annual economic sanction frequency (*Frequency*), economic and non-economic sanction source intensity (*Intensity*), weight emphasis to trade-related and financial sanctions (*Severity*), and economic sanction cumulative duration (*Duration*).

Presence: This binary variable indicates whether a country was subjected to economic sanctions (trade export, trade import, or financial) in a given year (value of "1") or not ("0"). This is based on the rationale of Felbermayr et al. (2021) and aligns with the work of Hagen and Schneider (2017), emphasizing the substantial influence of the mere presence of sanctions.

Frequency: Measures the annual frequency of economic sanctions, counting incidents targeting Trade Export, Trade Import, or Financial sectors. Grounded in the research of Wang et al. (2019) and Rarick and Han (2010), highlighting the compounded economic strain of multiple sanctions. Mathematical representation: $Frequency_t = \sum_{i=1}^{n} S_{i,t}$. where S indicates each sanction incident targeting Trade Export, Trade Import, or Financial in year t, n is the total number of sanction incidents in year t.

Intensity: Counts the number of sanction packages from various sources (USA, EU, UN, Others) in a year. According to Wang et al. (2019), this metric emphasizes the amplified impact of diverse international sources. Mathematical representation: $Intensity = USA + EU + UN + Others + sender\_mult$, where *sender_mult* represents the multiplicative effect of receiving sanctions from more than one source.

Severity: Assesses the overall impact of all sanction types, assigning double weight to economic sanctions (*Eco_S*), which include Trade Export, Trade Import, and Financial, and single weight to non-economic sanctions (*nonEco_S*), which include Arms, Military, Travel, and Other. This methodology is developed by Seyfi and Hall (2020) and Peksen (2019). Mathematical representation: $Severity = 2(\Sigma Eco\_S) + \Sigma nonEco\_S$.

Duration: Quantifies the consecutive years a country has been under sanctions, starting from 1992. The ongoing impact of sanctions, explored by Felbermayr et al. (2021), underscores the importance of considering cumulative duration. Each variable is carefully chosen to reflect the multifaceted nature of economic sanctions and their varying impacts on exchange rate volatility.

3.1.2.3. Control variables

In examining the impact of economic sanctions on exchange rate volatility, this study incorporates five control variables identified as significant in literature and empirical studies: GDP growth, inflation, interest rate, current account balance, and political stability.

Growth: GDP growth is measured annually in real terms and adjusted to 2010 USD. Kaboro et al. (2018) and Abdullah and Siddiqua (2015) highlight its significant dampening effect on exchange rate variability.

Inflation: Calculated as the annual percentage change in consumer prices, inflation generally nurtures a positive correlation with exchange rate volatility, signifying that higher inflation rates tend to fuel increased fluctuations in exchange rates, as demonstrated by Ndou and Gumata (2017).

Interest: The lending interest rate is used to examine its relationship with exchange rates, following the approach of Hacker et al. (2012).

Current: Measured as a percentage of GDP, the current account balance significantly influences exchange rate volatility, as suggested by Kuncoro and Fafurida (2023).

Political: Political stability is shown to affect exchange rate volatility. Aisen and Veiga (2008) and Suleman (2015) demonstrate its impact on exchange rate fluctuations and inflation rates. Each control variable contributes uniquely to understanding exchange rate volatility, providing a comprehensive framework for assessing the effects of economic sanctions.

3.1.2.3. Economic indicators

Reserves: Refers to total reserves, including gold (% of GDP). Studies by Hviding et al. (2004), Cady and Gonzalez-Garcia (2007), and Tavares (2015) underscore the relationship between ample reserve holdings and mitigation of exchange rate volatility.

3.2. Descriptive statistics

Table 2 presents the descriptive statistics for the study's variables. The volatility measure (*Vol*) shows an average of 5.64 and a high standard deviation of 14.65, indicating significant differences in volatility across the dataset. The binary variable *Presence* averages 0.71, with values ranging from 0 to 1. *Frequency*, reflecting economic sanction frequency, has an average of 5.92 and a standard deviation of 7.77, showing varied sanctioning frequencies. *Intensity* and *Severity* average 5.36 and 17.20, respectively, highlighting differing sanction intensities and frequencies. *Duration*, averaging 8.06 years, suggests prolonged sanctions in some instances.

Economic indicators such as *Growth*, *Inflation*, *Interest*, and *Current* show means of 3.49%, 2.06%, 13.99%, and –1.13%, respectively, with wide-ranging values. The *Political* variable, likely measuring political stability, has an average of –1.41, indicating varying political conditions in the sample. *Reserves*, representing foreign reserves, average 2.61 with a standard deviation of 1.26, pointing to diverse reserve levels across nations and time, ranging from –1.97 to 5.44.

Table 2
The descriptive statistics.

Variable	Observations	Mean	Std. dev.	Min	Max
Vol	441	5.64	14.65	0.74	225.29
Presence	441	0.71	0.45	0	1.00
Frequency	441	5.92	7.77	0	68.00
Intensity	441	5.36	5.30	0	42.00
Severity	441	17.20	20.12	0	171.00
Duration	441	8.06	8.28	0	30.00
Growth	441	3.49	7.39	–36.39	38.30
Inflation	422	2.06	1.09	–1.61	5.88
Interest	438	13.99	7.06	–15.69	65.42
Current	434	–1.13	11.72	–78.45	63.39
Political	438	–1.41	0.93	–3.18	0.83
Reserves	441	2.61	1.26	–1.97	5.44

Source: Authors' calculations.

These statistics collectively reveal a diverse dataset with significant variations across different variables.

It is important to note that our dataset, sourced from IMF, IFS, and WDI, underwent rigorous preparation to ensure accuracy and reliability. Specifically, for approximately 1–7% of missing data within each panel, we employed Multiple Imputation by Chained Equations (MICE), ensuring a statistically sound and coherent dataset. Moreover, to address the 1% of outlier data identified, we utilized the Winsorizing technique, thereby minimizing their influence and enhancing the dataset's overall quality.

3.3. Empirical method and analytical procedures

Before delving into model estimations, this research conducts preliminary tests to ensure data integrity. Firstly, a Pesaran and Xie (2021) cross-sectional dependence (CD) test is applied to check for interdependencies among variables, as such dependencies could bias the results. Next, the Augmented Dickey–Fuller (ADF) panel unit root test is used to verify the stationarity of the series, a crucial step for accurate analysis. The study proposes two primary models for estimation, presented in Equations 3 and 4. Equation 3 assesses the impact of individual explanatory variables on exchange rate volatility, while Equation 4 explores the interaction effects among these variables.

$$y_{it} = \alpha_i + \beta_1 X_{it} + \Sigma_j \beta_{j+2} W_{jit} + \epsilon_{it}, \tag{3}$$

$$y_{it} = \alpha_i + \beta_1 X_{it} + \beta_2 S_{it} + \delta(X_{it} \times S_{it}) + \Sigma_j \beta_{j+3} W_{jit} + \epsilon_{it}, \tag{4}$$

where y_{it} denotes the dependent variable exchange rate volatility; X_{it} and W_{jit} correspond to a set of independent explanatory variables; S_{it} stands for the sanction variable; δ — the coefficient for the interaction term; β — coefficients for independent variables; α_i is the constant specific; ϵ_{it} is an error term; i and t represent countries and periods, respectively.

For an in-depth analysis, we employed two advanced statistical models: PCSE and FGLS. The PCSE method, praised for its effectiveness in managing panels with cross-sectional dependence and addressing heteroskedasticity and serial correlation issues, follows the framework by Baily and Katz (2011). Additionally, for enhanced robustness, the FGLS method was used, acclaimed for its ability to handle panel-specific challenges and potential endogeneity. This method offers a refined alternative to Ordinary Least Squares (OLS) in scenarios of cross-sectional dependence, as noted by Bai et al. (2021).

4. Empirical results

4.1. Estimated results

4.1.1. Cross-sectional dependence (CD) test

Table 3 displays the CD test results. Except for the *Political* variable, which shows some cross-sectional independence, the null hypothesis of cross-sectional

Table 3
Cross-sectional dependence (CD).

Variable	Statistic	Prob.
Vol	11.22	0.000***
Growth	13.49	0.000***
Inflation	7.63	0.000***
Interest	6.98	0.000***
Current	12.20	0.000***
Political	1.28	0.200
Reserves	2.93	0.003***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

Table 4
Augmented Dickey–Fuller (ADF) panel unit root test.

Variable	Level I(0)	First difference I(1)
	z (t-bar)	z (t-bar)
Vol	–9.8463***	–26.7522***
Growth	–8.6058***	–23.3894***
Inflation	–4.5001***	–17.1991***
Interest	–2.7974***	–14.5833***
Current	–5.0142***	–18.1232***
Political	–0.6262	–13.1430***
Reserves	–2.7980***	–18.3412***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

independence is rejected at the 1% significance level for all other variables. This indicates a widespread presence of cross-sectional dependence across the dataset.

4.1.2. Panel unit root test

Table 4 presents the outcomes of the ADF panel unit root test for various economic variables. All variables exhibit stationarity at the level or first difference, as indicated by significant z (t-bar) values. The *Political* variable, however, is non-stationary at level (I(0)) but becomes stationary after first differencing (I(1)).

4.1.3. Regression estimates

4.1.3.1. Impact of sanctions and reserves on exchange rate volatility.

Our study explores the complex relationship between economic sanctions, total reserves, and exchange rate volatility, employing sophisticated statistical models: PCSE and FGLS. Their combination ensures a comprehensive analysis, adeptly managing cross-sectional dependence and heteroskedasticity, thus bolstering the credibility of our insights into the dynamics of economic sanctions, reserves, and exchange rate volatility.

The variable *Presence* in our models represents the influence of economic sanctions. The coefficients obtained from both the PCSE and FGLS models were positive and statistically significant (0.300**), as detailed in Table 5. This suggests

Table 5
Comparative analysis of sanctions' presence and reserves on exchange rate volatility.

Vol	PCSE			FGLS		
	(1)	(2)	(3)	(4)	(5)	(6)
Presence		0.300**	0.026		0.300**	0.0252
		(0.132)	(0.200)		(0.118)	(0.182)
Presence × Reserves			0.0132**			0.0132**
			(0.006)			(0.007)
Reserves	–0.00430**	–0.00469**	–0.0171***	–0.00427**	–0.00463**	–0.0171***
	(0.002)	(0.002)	(0.006)	(0.002)	(0.002)	(0.007)
Growth	–0.0364***	–0.0348***	–0.0344***	–0.0369***	–0.0352***	–0.0348***
	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)
Inflation	0.00471**	0.00419*	0.00414*	0.00457**	0.00406**	0.00400*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Interest	0.0192**	0.0177**	0.0167**	0.0194**	0.0179**	0.0169**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Current	–0.00675*	–0.00685*	–0.00690*	–0.00725	–0.00733*	–0.00739*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Political	0.0655	0.0731	0.0793	0.0646	0.0725	0.0789
	(0.162)	(0.158)	(0.158)	(0.161)	(0.160)	(0.160)
Constant	0.949***	0.765***	1.037***	0.949***	0.765***	1.037***
	(0.216)	(0.212)	(0.272)	(0.151)	(0.166)	(0.214)

Notes: Observations = 412, number of id = 21. Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

that there is a direct relationship between economic sanctions and an increase in exchange rate volatility. This finding validates our Hypothesis H1, providing evidence that economic sanctions have a substantial impact on the volatility of exchange rates.

The variable *Reserves*, which represents the ratio of total reserves (including gold) to GDP, exhibited negative and statistically significant coefficients (ranging from –0.00430** to –0.0171***) across the models. These findings indicate that a higher ratio of reserves to GDP is linked to a decrease in the level of fluctuation in exchange rates, supporting our Hypothesis H2. A higher ratio of total reserves (including gold) to GDP is associated with a reduction in exchange rate volatility.

In both models, we found a positive and statistically significant coefficient (0.0132**) for the interaction term *Presence* × *Reserves*. This finding indicates that when economic sanctions are in effect, a combination of stricter sanctions and increased reserves results in a greater volatility of the exchange rate. This finding confirms Hypothesis H3, suggesting that despite a country's high reserves relative to its GDP, they are not adequate to completely stabilize exchange rate volatility within the context of economic sanctions.

4.1.3.2. Alternative sanctions measures.

To ensure robustness and validity, our analysis evaluates economic sanctions' multifaceted nature using metrics: *Frequency*, *Intensity*, *Severity*, and *Duration*, as outlined in subsection 3.1.2. These metrics offer a nuanced understanding of sanctions' implications.

In the comprehensive analysis presented in Table 6, we delve into the influence of these factors on exchange rate volatility, correlating them with our study's hypotheses H1, H2, and H3. The results are as follows.

Table 6
Multifaceted sanctions metrics and their influence on exchange rate volatility.

Vol	PCSE				FGLS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Frequency	0.0199*				0.0200**			
	(0.010)				(0.009)			
Frequency × Reserves	0.000653***				0.000640**			
	(0.000)				(0.000)			
Intensity		0.0355**				0.0357***		
		(0.014)				(0.012)		
Intensity × Reserves		0.000687**				0.000672**		
		(0.000)				(0.000)		
Severity			0.00894**				0.00896***	
			(0.004)				(0.003)	
Severity × Reserves			0.000212**				0.000209**	
			(0.000)				(0.000)	
Duration				0.00263				0.00291
				(0.011)				(0.009)
Duration × Reserves				0.000566***				0.000559***
				(0.000)				(0.000)
Reserves	–0.00968***	–0.0104***	–0.0102***	–0.0141***	–0.00954***	–0.0102***	–0.0100***	–0.0139***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
Growth	–0.0313***	–0.0327***	–0.0311***	–0.0344***	–0.0318***	–0.0331***	–0.0315***	–0.0348***
	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)
Inflation	0.0028	0.00213	0.00276	0.00352	0.00274	0.00208	0.0027	0.00342
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Interest	0.0167**	0.0153*	0.0153*	0.0167**	0.0168**	0.0154**	0.0154**	0.0168**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)
Current	–0.00464	–0.00462	–0.00533	–0.00728*	–0.00486	–0.00483	–0.00553	–0.00755*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Political	0.121	0.127	0.130	0.0734	0.119	0.125	0.129	0.0727
	(0.152)	(0.151)	(0.152)	(0.157)	(0.156)	(0.157)	(0.156)	(0.159)
Constant	0.911***	0.889***	0.906***	1.072***	0.910***	0.888***	0.905***	1.069***
	(0.225)	(0.233)	(0.226)	(0.245)	(0.153)	(0.157)	(0.152)	(0.167)

Notes: Observations = 412, number of id = 21. Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

Hypothesis 1: Economic sanctions contribute to an increase in exchange rate volatility. The *Frequency* metric shows positive coefficients (0.0199* in PCSE, 0.0200** in FGLS), indicating that more frequent economic sanctions lead to greater volatility. *Intensity*' has positive coefficients (0.0355** in PCSE, 0.0357*** in FGLS), suggesting increased volatility with more intense sanctions. *Severity* also displays positive coefficients (0.00894** in PCSE, 0.00896*** in FGLS), signifying higher volatility with more severe trade and finance-related sanctions. *Duration*, while positive, is not statistically significant, indicating a more complex, time-dependent impact.

Hypothesis 2: A higher ratio of total reserves to GDP reduces exchange rate volatility. *Reserves*: Negative coefficients across models (from –0.00968*** to –0.0141***) demonstrate a correlation between higher reserves and lower volatility.

Hypothesis 3: A combination of heightened sanctions and elevated reserves leads to increased exchange rate volatility. The interaction terms *Frequency* × *Reserves* and *Intensity* × *Reserves* show positive coefficients (0.000653*** in PCSE, 0.000640** in FGLS for the former and 0.000687** in both PCSE and FGLS for the latter), indicating increased volatility under these combined conditions. Similarly, *Severity* × *Reserves* also shows positive coefficients (0.000212** in PCSE, 0.000209** in FGLS), suggesting that severe sanctions, even with substantial reserves, contribute to increased volatility.

In conclusion, our analysis proves that economic sanctions correlate positively with increased exchange rate volatility. It further corroborates that a higher ratio of reserves to GDP is generally associated with a decrease in exchange rate fluctuations. However, even significant reserves in proportion to GDP are not adequate to thoroughly neutralize the destabilizing influence of economic sanctions on exchange rate volatility. Additionally, the employment of diverse sanction measures used for robustness analysis consistently demonstrates a positive correlation with increased exchange rate volatility. This underscores the substantial and far-reaching impact of sanctions on financial market stability. Our investigation provides essential insights into the intricate dynamics of economic policies and their effects on currency markets.

4.1.3.3. Exploring the inverse relationship between the reserve-to-GDP ratio and economic growth under sanctions

Next, we shift our focus to the exploration of the inverse relationship between the reserve-to-GDP ratio and economic growth. This segment of our research delves into the impact of economic sanctions on a nation's economic growth, with particular emphasis on how a country's accumulation of reserves relative to its GDP is influenced. We utilize PCSE within a fixed-effect model to thoroughly examine various facets of sanctions, encompassing their *Frequency*, *Intensity*, *Severity*, and *Duration*. This analysis is conducted in conjunction with the reserves-to-GDP ratio as outlined in Equation 5.

$$G_{it} = \alpha_i + \beta_j X_{jit} + \gamma_i + \delta_t + \epsilon_{it}, \tag{5}$$

where G_{it} represents the growth rate of country i in year t; X_{jit} is a set of explanatory variables including the reserves-to-GDP ratio (*Reserves*); α_i, γ_i, δ_t and ϵ_{it} represent intercept, country-specific effects, time effects, and the error term, respectively.

Table 7
Relationship between reserve-to-GDP ratio and economic growth under sanctions.

Growth	(1)	(2)	(3)	(4)	(5)
Presence	–2.882***				
	(0.891)				
Frequency		–0.202***			
		(0.0556)			
Intensity			–0.293***		
			(0.0860)		
Severity				–0.0820***	
				(0.0216)	
Duration					–0.231***
					(0.0727)
Reserves	–1.509*	–1.696**	–1.611*	–1.683**	–1.741**
	(0.833)	(0.832)	(0.833)	(0.830)	(0.838)
Inflation	–1.300***	–1.176***	–1.087**	–1.134***	–1.058**
	(0.419)	(0.421)	(0.429)	(0.422)	(0.435)
Interest	–0.0284	–0.00615	–0.00617	–0.00365	–0.0489
	(0.080)	(0.0770)	(0.0771)	(0.0768)	(0.0793)
Current	0.251***	0.230***	0.225***	0.224***	0.234***
	(0.040)	(0.0388)	(0.0394)	(0.0391)	(0.0390)
Constant	8.926***	7.513***	7.688***	7.594***	8.526***
	(1.380)	(1.210)	(1.230)	(1.210)	(1.330)
Country Fixed Effects	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES

Notes: Observations = 396. Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

In Model 1 from Table 7, the reserves-to-GDP ratio (*Reserves*) coefficient of –1.509* indicates an inverse relationship between this ratio and economic growth in countries experiencing sanctions, thereby supporting Hypothesis 4 (H4). This outcome suggests that an elevated reserves-to-GDP ratio during periods of sanctions may reflect a decrease in GDP rather than an actual increase in reserves. Additionally, the coefficient for the Presence of Sanctions (*Presence*) at –2.882*** significantly highlights the detrimental impact of sanctions on economic growth, affirming that the presence of sanctions adversely affects a country's economic performance.

This trend continues across Models 2 to 5, which consistently exhibit negative coefficients for the reserves-to-GDP ratio (–1.696** in Model 2, –1.611* in Model 3, –1.683** in Model 4, and –1.741** in Model 5), further corroborating the inverse relationship between reserves and economic growth in countries under sanctions. Furthermore, the coefficients for various sanctions variables: –0.202*** for *Frequency*, –0.293*** for *Intensity*, –0.0820*** for *Severity*, and –0.231*** for *Duration* — consistently reveal the adverse impact of sanctions in all models. These findings underscore the extensive negative consequences that sanctions impose on economic health, irrespective of their specific characteristics.

Fig. 2 depicts the trends in GDP growth and reserves as a percentage of GDP over a period from 2002 to 2022 in the context of sanctions. The top graph shows the fluctuation in average GDP growth, with a noticeable volatility throughout the years. The bottom graph illustrates the average total reserves, including gold, as a percentage of GDP, which demonstrates a substantial increase over the same period. The visual contrast between these two metrics accentuates the inverse rela-

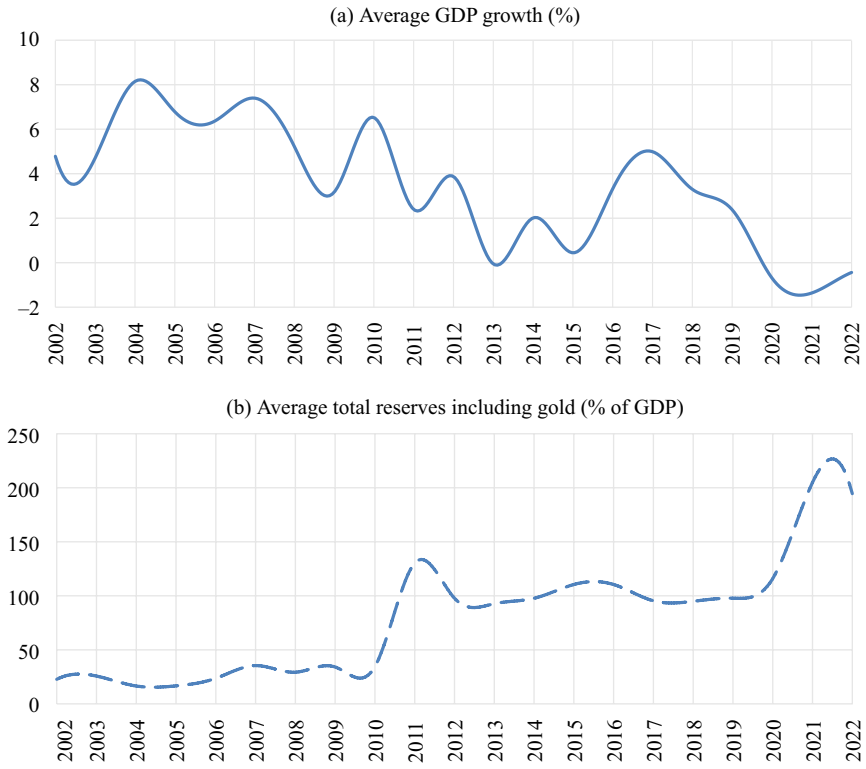

Fig. 2. Trends in GDP growth and reserves (% of GDP) in the context of sanctions.

Source: Authors' calculations.

tionship postulated in Hypothesis 4. At the same time, reserves appear to rise, and GDP growth displays a contrasting trend, with periods of increase often followed by declines. This visual representation corroborates the quantitative findings from Table 7, offering a clear depiction of economic dynamics that sanctioned countries face, particularly in terms of reserves accumulation and GDP growth.

5. Discussion

The in-depth study delving into the interplay between economic sanctions, total reserves, and exchange rate volatility across 21 countries over two decades marks a significant departure from traditional economic theories. Predominantly, it challenges the longstanding belief that amassing substantial reserves is an effective shield against exchange rate disturbances, particularly in the context of economic sanctions. Using sophisticated methodologies like PCSE and FGLS, the research offers a nuanced perspective, suggesting that in sanctioned environments, robust reserves might not safeguard against exchange rate fluctuations as effectively as traditionally believed. This revelation is critical as it calls for a rethinking of economic strategies both at the national and international levels.

Our analysis reveals significant insights into the dynamics of economic sanctions, reserves, and exchange rate volatility and their collective impact on economic growth. These findings are pivotal for understanding global financial systems and formulating effective economic policies. Our study establishes a clear

positive correlation between the presence of economic sanctions and increased exchange rate volatility. This is crucial in the field of international finance and economics, demonstrating how geopolitical decisions can significantly impact market dynamics. Exchange rates, being of utmost importance for a country's trade level and economic stability, become volatile in the face of sanctions. This volatility arises from reduced investor confidence and disruptions in trade flows, which are expected consequences of sanctions. The *Presence* of sanctions, along with their *Frequency*, *Intensity*, *Severity*, and *Duration*, leads to heightened market uncertainty and risk, reflected in exchange rate fluctuations. This volatility, especially pronounced in globalized financial markets, highlights far-reaching effects of geopolitical actions on economic stability.

Moreover, in the context of sanctions, nations often face tangible constraints such as asset freezes or limitations on accessing their reserves, which can significantly undermine the effectiveness of their reserves as a financial safety net. These constraints not only exacerbate the volatility of exchange rates, as the usual buffer provided by reserves is weakened or rendered inaccessible, but also highlight a pivotal shift in strategy focus from the sheer size of reserves to their safety and accessibility. Specifically, sanctions hinder access to various components of the Global Financial Safety Net that are normally open to a country under standard circumstances, such as IMF financing, regional financial arrangements' funds, and budget financing from MDBs, disbursed under highly concessional terms. This leaves a country reliant primarily on its Market Risk Assessments (MRA) once large-scale sanctions are in place. The significant work by Vinokurov et al. (2022) underscores this critical shift arguing that the primary issue in the face of sanctions is not the size of reserves but their safety and accessibility.

Our findings also show that a higher reserves-to-GDP ratio is generally associated with reduced exchange rate volatility. This supports the economic theory that reserves act as a buffer against external shocks, including market fluctuations. Higher reserves, indicative of a country's financial strength, can enhance investor confidence and contribute to more stable economic conditions. However, it is essential to recognize that merely accumulating reserves is not a complete solution to economic challenges, particularly in complex geopolitical situations.

Notably, our analysis reveals that high reserves relative to GDP do not fully stabilize exchange rate volatility in the presence of economic sanctions. Sanctions can lead to severe trade disruptions and reduced economic activity, diminishing the effectiveness of reserves as a stabilizing tool. This finding is significant for policymakers, suggesting the need for a holistic approach to economic stability that considers reserve accumulation and strategies to counteract the impacts of sanctions. Moreover, we observed an inverse relationship between higher reserves-to-GDP ratios during sanctions and economic growth. This relationship indicates that an increased reserves-to-GDP ratio, often seen during periods of sanctions, may reflect a struggling economy rather than actual economic strength. The accumulation of reserves in such situations is more likely a defensive strategy against the uncertainties of sanctions rather than a sign of economic prosperity. This finding has profound implications for economic policy, highlighting the need for strategies that focus on stimulating economic growth and diversifying the economy rather than solely on reserve accumulation.

These insights are crucial for policymakers, particularly in countries susceptible to sanctions. They underscore the necessity of broad-based economic resilience strategies and emphasize the importance of ensuring accessibility to reserves during crises. Additionally, the study calls for a reevaluation of risk assessments and the development of global financial frameworks that mitigate the adverse effects of sanctions. Such frameworks should foster a more informed and collaborative approach to managing global economic challenges promoting stability and growth. In conclusion, our study contributes to a nuanced understanding of the complex interactions between reserves, exchange rate volatility, and economic sanctions. It underscores the importance of multifaceted economic policies and international cooperation in navigating these challenges effectively, ensuring economic stability and growth in an interconnected global economy.

The research, while insightful, acknowledges certain limitations. Primarily, its focus on data from 2002 to 2022 may not capture the complete spectrum of economic behaviors, particularly in the evolving post-2022 global economy. This is especially true in the cases of Russia and Belarus, where the number of sanctions has increased significantly post-2022. However, due to data availability at this point, a comprehensive analysis reflecting these changes is beyond the scope of the current study. Additionally, the selection of 21 countries, though diverse, might only partially represent the global economic landscape, especially considering countries with unique economic conditions or experiences with sanctions. The methodologies used, namely Panel-Corrected Standard Errors and Feasible Generalized Least Squares, have inherent assumptions and biases. These models, while providing substantial insights, may not fully encompass all aspects of economic sanctions and their effects, particularly given the complex and multifaceted nature of sanctions.

To address these limitations, future research could expand the timeline to include a more comprehensive historical analysis and broaden the country selection for a more global perspective. Exploring alternative econometric models or methodologies could offer different viewpoints, and a deeper examination of the specifics of economic sanctions could enhance understanding of their broader implications. Incorporating a broader set of control variables, such as global economic shifts and geopolitical dynamics, and employing primary data collection methods or data triangulation techniques would strengthen the robustness of the findings. Furthermore, integrating socio-political analysis with economic factors in a multidisciplinary approach would enrich the understanding of the intricate dynamics affecting countries under sanctions. Additionally, future studies should consider the impact of different monetary policy regimes to further elucidate the complex interplay between sanctions, monetary policies, and exchange rate volatility, addressing a critical gap identified in our current research framework.

This study represents a significant shift in the understanding of global economic dynamics, challenging conventional theories and emphasizing the need for nuanced, context-aware approaches in international economic relations. It highlights the complex interplay between economic sanctions, reserves, and exchange rate volatility, revealing that even substantial reserves cannot always mitigate the destabilizing effects of sanctions. These findings underscore the importance of reevaluating traditional economic strategies and call for more informed, collaborative policymaking to navigate the interconnected global economy ef-

fectively. The research is crucial for policymakers, illuminating the far-reaching consequences of sanctions and the necessity of adaptive economic policies in an evolving global landscape.

6. Conclusions and policy implications

Our extensive research, spanning two decades (2002–2022) and encompassing 21 countries, utilized advanced econometric methods like Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) to explore the complex relationship between economic sanctions, total reserves, and exchange rate volatility. The findings from this study offer critical insights for policy implications:

- *Economic sanctions and exchange rate volatility:* The analysis confirms that economic sanctions are positively correlated with higher exchange rate volatility.
- *Effect of higher reserves:* A higher ratio of reserves to GDP is generally linked to reduced exchange rate volatility.
- *Interaction effect in sanctions context:* Even when a country holds high reserves in proportion to its GDP, these are not sufficient to fully stabilize exchange rate volatility in the presence of economic sanctions.
- *Varying dimensions of sanctions:* Different characteristics of sanctions, such as their frequency and intensity, consistently show a positive correlation with increased exchange rate volatility, underscoring the broad impact of sanctions.
- *Inverse relationship with economic growth:* The higher reserves-to-GDP ratio during periods of sanctions is associated with decreased economic growth, highlighting the negative economic consequences of sanctions.

The study calls for a paradigm shift in how nations approach economic policymaking, especially under the shadow of sanctions. It emphasizes the need for adaptive, multifaceted strategies that consider the broader global economic context, advocating for international cooperation and a collaborative approach to global economic governance. These strategies are essential not only for individual nations but also for the stability and prosperity of the global economy.

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