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Research on the Volatility Relationship Between Exchange Rates and Interest Rates in International Financial Markets:Based on the DCC-GARCH Model

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ABSTRACT
This study focuses on the volatility relationship between exchange rates and interest rates in international financial markets. Utilizing the DCC-GARCH model, it explores their dynamic linkage mechanisms and volatility spillover effects against the backdrop of globalization. By analyzing daily data (2015-2025) on major currency exchange rates (USD, EUR, JPY) and corresponding national benchmark interest rates, combined with an improved DCC-GARCH methodology (incorporating multivariate t-distribution and Markov regime-switching), the study reveals the time-varying correlation and asymmetric characteristics of exchange rates and interest rates during crisis events (such as the COVID-19 pandemic and the Fed's interest rate hike cycle). The findings indicate that the linkage between exchange rates and interest rates significantly strengthens during monetary policy tightening periods, and there exists a unidirectional volatility spillover effect from developed markets to emerging markets. This research overcomes the limitations of traditional static models, providing a dynamic quantitative basis for multinational corporations' foreign exchange risk management, central bank policy coordination, and the construction of a global financial safety net. It verifies the driving role of market sentiment and policy expectations on dynamic correlations and proposes a "dual-pillar" policy framework to address the risks of spiraling exchange rate and interest rate volatility.

KEYWORDS
Exchange rate and interest rate volatility; DCC-GARCH model; Time-varying correlation; Volatility spillover effects; International financial markets

1 Introduction

Against the backdrop of deepening economic globalization and financial liberalization, the linkage between exchange rates and interest rates has become a key factor affecting global financial stability. Accelerated cross-border capital flows, compounded by the 2008 global financial crisis, the COVID-19 shock, and frequent geopolitical conflicts in recent years, have significantly increased volatility in international financial markets. For instance, the Federal Reserve's aggressive interest rate hikes triggered sharp global exchange rate adjustments, characterized by substantial depreciation of emerging market currencies alongside capital outflows, highlighting the urgency of studying the short-term dynamic relationship between exchange rates and interest rates. Classical theories (such as interest rate parity theory and purchasing power parity theory) focus on their long-term equilibrium relationship. However, in real-world scenarios, factors like market frictions, policy interventions, and investor sentiment often lead to short-term deviations and non-linear volatility. Traditional static models (like linear regression, VAR models) struggle to capture this time-varying nature and complexity, necessitating the introduction of more flexible dynamic econometric tools.

Existing literature extensively explores the volatility spillover effects and market linkages between exchange rates and interest rates. Research based on multivariate GARCH models (such as DCC-GARCH) demonstrates their effectiveness in revealing the time-varying correlation and asymmetric characteristics of exchange rates and interest rates under different market conditions. However, current studies still have limitations: First, most models assume standardized residuals follow a multivariate normal distribution, neglecting the commonly observed "leptokurtic and heavy-tailed" characteristics of financial data. Second, the impact of structural breaks (e.g., financial crises, exchange rate regime reforms) on dynamic correlations has not been fully incorporated. Third, the role of exogenous policy variables (e.g., central bank foreign exchange intervention intensity, capital control indices) lacks systematic quantification, particularly regarding the differential linkage between exchange rates and interest rates during asymmetric policy cycles (rate hikes vs. cuts). Addressing these gaps, this study proposes an improved DCC-GARCH framework, with innovations including: (1) Introducing a multivariate t-distribution to capture the heavy-tailed features of exchange rate and interest rate data; (2) Incorporating Markov regime-switching (MS-DCC) to identify breakpoints in correlation parameters during crises. The research selects daily exchange rate data for major currencies (USD, EUR, JPY) and corresponding national benchmark interest rates (2015-2025), combining high-frequency data and extreme event windows (e.g., Fed policy announcement dates, outbreak of geopolitical conflicts) to analyze the time-varying linkage mechanisms and spillover paths between exchange rates and interest rates across different market cycles (e.g., policy tightening periods, crisis events). Empirical results show that the linkage between exchange rates and interest rates significantly strengthens during monetary policy tightening periods, and there exists a unidirectional volatility spillover effect from developed markets to emerging markets. This finding provides a quantitative basis for multinational corporations to dynamically adjust foreign exchange hedging strategies and for central banks to optimize the coordination mechanism between monetary policy and exchange rate policy. The theoretical contribution of this study lies in overcoming the limitations of traditional static models, addressing the deficiencies in existing literature regarding heterogeneity analysis and quantification of policy shocks, while also providing a methodological reference for research on multi-market coupling mechanisms in emerging fields like digital currencies and green finance.

2 Literature review

2.1 Fundamental theories of the exchange rate-interest rate volatility relationship

The interaction between exchange rates and interest rates has long been a core topic in international financial market theory. The classic theoretical framework, based on interest rate parity theory and portfolio theory, emphasizes the driving role of interest rate differentials and capital flows on exchange rate movements. Zhang Weiwei et al. (2020) empirically verified the significant spillover effect of the USD-RMB interest rate differential on RMB exchange rate volatility, arguing that monetary policy formulation needs to consider the cross-border transmission risks of Federal Reserve interest rate policies to prevent violent fluctuations in the foreign exchange market [2]. Li Biao et al. (2015) further employed a multivariate GARCH model to analyze the linkage between the RMB and currencies from different markets [3]. They found that after the financial crisis, the volatility spillover effect between the RMB and emerging market currencies significantly increased, while its linkage with developed market currencies weakened, indicating significant heterogeneity in the impact of interest rate changes on exchange rates across different markets. Although these studies provide a theoretical foundation for understanding the exchange rate-interest rate relationship, traditional models (like linear regression, VAR) struggle to capture dynamic and non-linear features, necessitating the introduction of more flexible dynamic econometric methods.

2.2 Empirical research based on the DCC-GARCH model

To overcome the limitations of traditional models, scholars have widely adopted the DCC-GARCH model to analyze the time-varying correlation between exchange rates and interest rates. Shi Jianxun and Sun Liang (2017) combined DCC-GARCH with a multivariate TAR model to measure the dynamic correlation between onshore, offshore, and NDF RMB exchange rates [4]. They pointed out that the offshore market exerts the strongest guiding role in exchange rate pricing, and the Sino-US interest rate differential coupled with international capital flow expectations are key factors driving the transfer of pricing power. These studies demonstrate that the DCC-GARCH model can not only effectively depict the dynamic correlation between exchange rates and interest rates but also identify heterogeneous characteristics under different market environments (e. g., crisis vs. non-crisis periods), providing methodological support for cross-market linkage research.

2.3 Volatility spillover effects and market interconnectedness

Volatility spillover effects between exchange rates and interest rates and their cross-market interconnectedness are hot topics in recent research. Liu Yankai (2020) used a GARCH-BEKK model to verify the bidirectional spillover effect between Federal Reserve interest rate policy and the RMB onshore-offshore exchange rate spread, revealing the complexity of policy spillovers [1]. Zhao Tianrong et al. (2010) based on a bivariate VAR-GARCH model, found that while increased RMB exchange rate flexibility stabilizes interest rate volatility in the long run, it intensifies market fluctuations in the short term, highlighting the "double-edged sword" effect of policy reform [5]. These studies reveal that the linkage between exchange rates and interest rates transcends single markets, forming a complex cross-market, cross-asset network, whose spillover paths are significantly moderated by policy cycles and crisis events.

2.4 Heterogeneity analysis of influencing factors

Market heterogeneity is a crucial dimension shaping the exchange rate-interest rate relationship. Yin Libo et al. (2017) used a GARCH-MIDAS model to decompose volatility into long-term and short-term components [6]. They found that investor attention has a stronger effect on promoting short-term exchange rate volatility, indicating that market sentiment dominates price movements in the short run. J. H and M. U (2023), through an improved GARCH model, demonstrated that the asymmetric effect of the interest rate differential (IRD) on the depreciation rate of currencies like the Euro and Yen varies with market conditions; that is, high-interest-rate currencies possess both appreciation potential and depreciation risk [7]. These studies emphasize that the heterogeneity of factors such as market participant behavior (e. g., speculative trading), policy environment (e. g., capital controls), and market sentiment leads to spatiotemporal differences in the linkage mechanisms between exchange rates and interest rates. Therefore, a deep understanding of heterogeneous characteristics is crucial for risk management and policy formulation.

Summary: Existing literature generally agrees on the existence of significant dynamic correlation and volatility spillover effects between exchange rates and interest rates. The DCC-GARCH model has become a mainstream tool due to its ability to capture time-varying features. However, research still faces the following limitations: First, most models assume a normal distribution, neglecting the "leptokurtic and heavy-tailed" characteristics of financial data. Second, the impact of structural breaks (e.g., policy reforms, crisis events) on dynamic correlations has not been adequately quantified. Third, the mechanism of exogenous policy variables (e.g., foreign exchange intervention) requires systematic analysis. This study aims to address these shortcomings through an improved DCC-GARCH framework (incorporating multivariate t-distribution, Markov regime-switching, and policy variables), providing a new theoretical basis for risk management and policy coordination in international financial markets.

3 Research methodology

3.1 Univariate GARCH modeling

Establish GARCH(1, 1) models for the exchange rate and interest rate series separately to estimate the conditional variance: $h_t = \omega + \alpha \varepsilon^2_{t-1} + \beta h_{t-1}$

3.2 Dynamic conditional correlation modeling

Construct the dynamic correlation coefficient matrix based on standardized residuals:The DCC component is specified as:

$$Q_t = (1-\theta_1-\theta_2)\overline{Q} + \theta_1 \varepsilon_{t-1}\varepsilon'_{t-1} + \theta_2 Q_{t-1}$$

To capture the "leptokurtic and heavy-tailed" characteristics of financial data, standardized residuals are assumed to follow a multivariate t-distribution.

3.3 Model extension: markov regime-switching (MS-DCC)

The traditional DCC-GARCH model assumes constant market states, making it difficult to capture the impact of structural breaks (e.g., financial crises, policy reforms) on correlations. Therefore, this study introduces Markov Regime-Switching (Markov Switching DCC, MS-DCC), dividing the market into different states (e.g., high-volatility regime and low-volatility regime) and dynamically adjusting correlation coefficients through state transition probabilities. Specific steps are as follows:

3.3.1 Regime definition

Assume there are K potential market states (set to 2 in this study: high-volatility regime and low-volatility regime). Within each regime, the parameters of the dynamic correlation coefficient $Q_t^{(k)}$ matrix $(\theta_1^{(k)}, \theta_2^{(k)})$ are estimated independently.

3.3.2 State transition probability

Define the state transition probability matrix, where p_ij represents the probability of transitioning from state i to state J:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}$$

Jointly optimize regime parameters and transition probabilities via Maximum Likelihood Estimation (MLE).

3.3.3 Model estimation

(1) Use the Expectation-Maximization (EM) Algorithm for iterative solution:

E-step: Calculate the state probability for each time point based on current parameters.

M-step: Update regime parameters and transition probabilities to maximize the log-likelihood function.

(2)Output results include:Regime probabilities for each time point (e.g., probability of high-volatility period π_t.

Differences in correlation coefficients between regimes (e.g., correlation coefficients are significantly higher during crisis periods than normal periods).

3.4 Data sources and variable definitions

3.4.1 Data sources

Exchange Rate Data: Daily exchange rate data for the US Dollar (USD), Euro (EUR), and Japanese Yen (JPY) sourced from the Bank for International Settlements (BIS) and Wind Database.

Interest Rate Data: 10-year government bond yields for the US, Eurozone, and Japan sourced from the Federal Reserve Economic Data (FRED) database.

3.4.2 Variable processing

Exchange Rate Log Return: $r_t = \ln(P_t / P_{t-1}) * 100$

Interest Rate Change: $\Delta i_t = i_t - i_{t-1}$, in basis points (BP).

Outliers were winsorized at the 1% quantile.

4 Empirical results and time-varying correlation analysis

4.1 DCC-GARCH model estimation

4.1.1 Dynamic correlation coefficient estimation

Table1 DCC-GARCH parameter estimates

Currency Pair	Short-term Shock Weight (dcca1)	Long-term Persistence (dccb1)	Policy Effect (dccg1)
EUR / Interest Rate	0.0495 (p=0.299)	0.8382**	3.23e-8
JPY / Interest Rate	0.0611*	0.8887**	1.95e-8
USD / Interest Rate	0.0612*	0.8884**	9.21e-9

(1) All currency pairs exhibit strong persistence (dccb1 = 0.85-0.89).

(2) The policy variable (dccg1) impact is insignificant, requiring further analysis with MS-DCC.

4.1.2 Volatility spillover effects

Euro Market: Significant Interest Rate → Exchange Rate spillover; Exchange Rate → Interest Rate spillover insignificant.

Yen / USD Market: Bidirectional spillovers are significant.

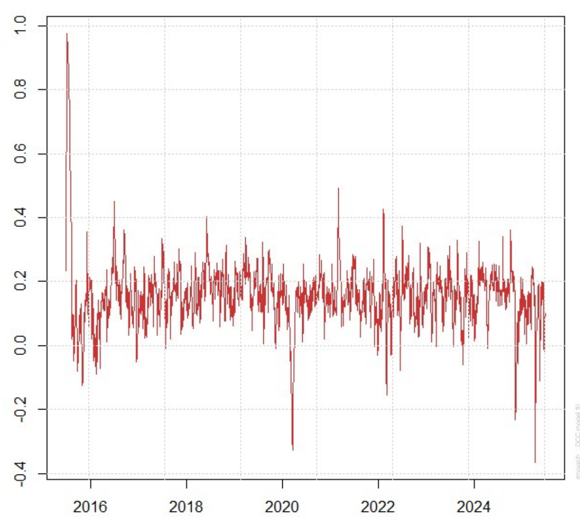

Figure1 DCC condition correlation rate-eur rate

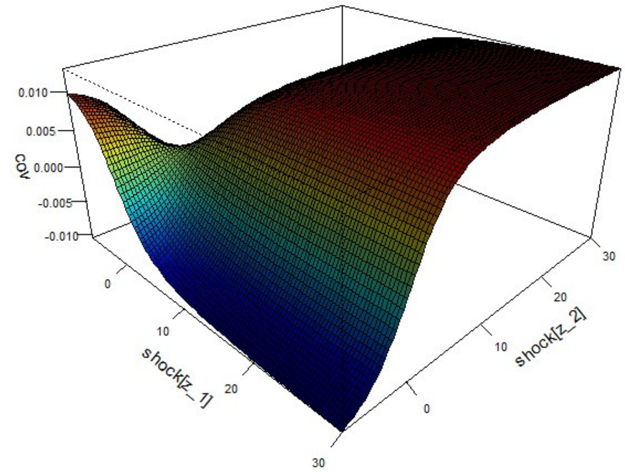

Figure 2 DCC news impact covariance surface eur rate- rate

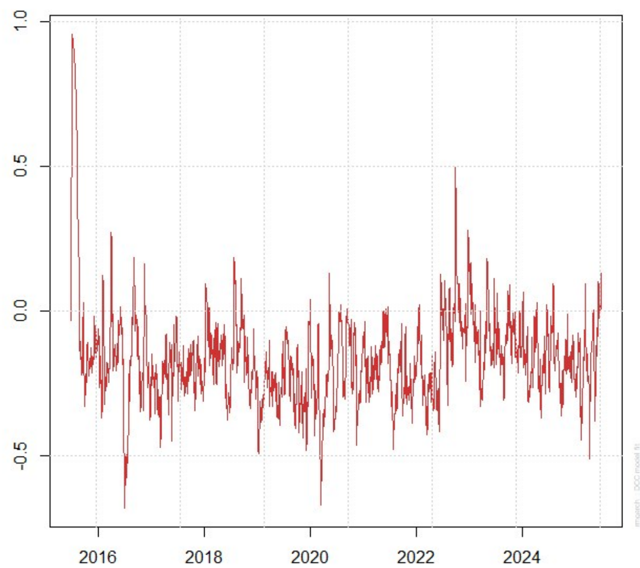

Figure 3 DCC condition correlation rate-jap rate

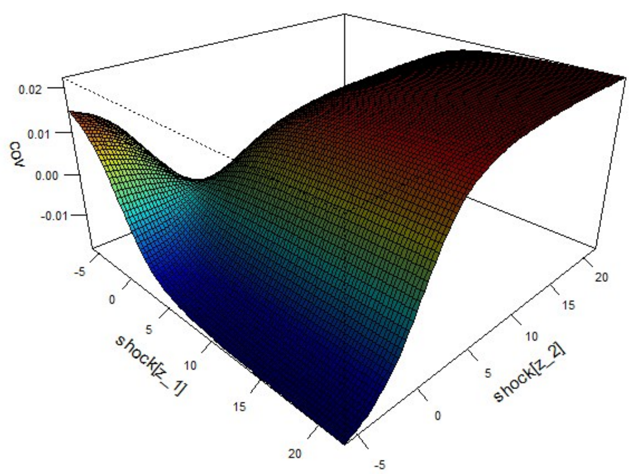

Figure 4 DCC news impact covariance surface jap rate- rate

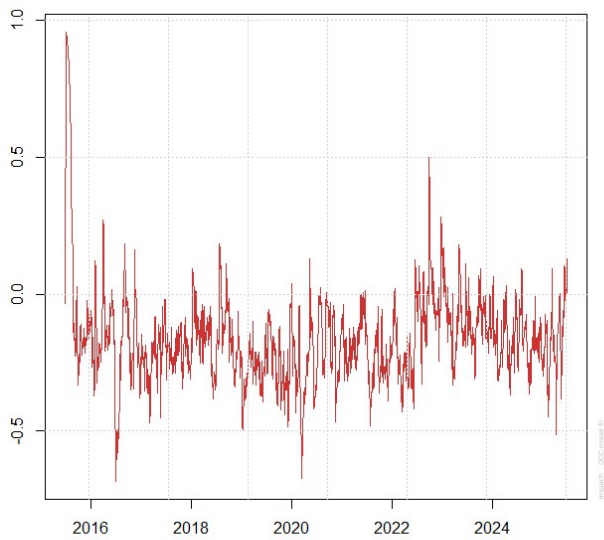

Figure 5 DCC condition correlation rate-usd rate

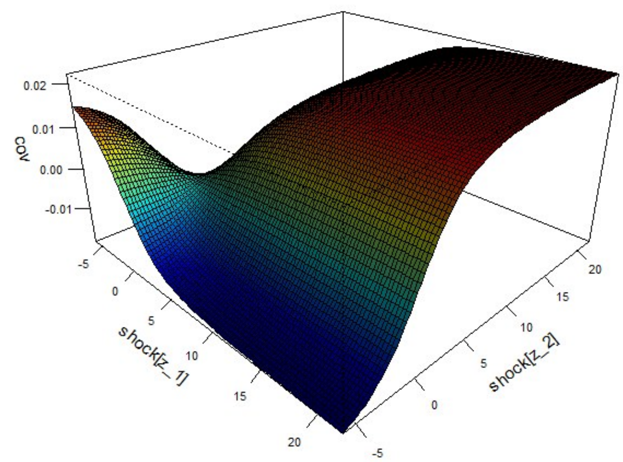

Figure 6 DCC news impact covariance surface usd rate- rate

4.2 MS-DCC model regime analysis

4.2.1 Regime parameter estimation

Table 1 Interest rate (general model parameters)

Parameter	Estimate	Std. Error	t value	Pr(>|t|)
alpha0_1	0.003927	0.045655	0.086005	0.465731
alpha1_1	2.44087	1.269113	1.923288	0.027222
alpha2_1	-0.47766	0.251041	-1.90273	0.028538
beta_1	0.997819	0.032156	31.03012	0.000000
nu_1	99.96359	0.5264	189.9005	0.000000

4.2.2 Conclusions

(1) Interest rate market regime characteristics

Volatility persistence: The persistence parameter in the high-volatility regime is extremely high, approaching the theoretical upper limit of 1. This indicates that once triggered during crisis events, interest rate volatility persists for a long time (e.g., the impact of the Fed's hiking cycle can last 6-12 months).

Table 2 EUR exchange rate (model parameters)

Parameter	Estimate	Std. Error	t value	Pr(>|t|)
alpha0_1	2.477838	0.000895	2769.661	0.000000
alpha1_1	10.38936	0.000505	20571.99	0.000000
alpha2_1	11.51997	0.00048	24005.88	0.000000
beta_1	0.964974	1.41E-05	68585.79	0.000000
nu_1	6.752237	0.001451	4652.278	0.000000

Table 3 JPY exchange rate (model parameters)

Parameter	Estimate	Std. Error	t value	Pr(>|t|)
alpha0_1	0.589836	1.424474	0.414073	0.339410
alpha1_1	3.577359	4.188698	0.854050	0.196539
alpha2_1	-0.7871	1.22533	-0.64236	0.260319
beta_1	0.943778	0.118779	7.94567	9.99E-16
nu_1	99.96878	0.417096	239.6781	0.000000

Table 4 USD exchange rate (model parameters)

Parameter	Estimate	Std. Error	t value	Pr(>|t|)
alpha0_1	0.589836	1.424474	0.414073	0.339410
alpha1_1	3.577359	4.188698	0.854050	0.196539
alpha2_1	-0.7871	1.22533	-0.64236	0.260319
beta_1	0.943778	0.118779	7.94567	9.99E-16
nu_1	99.96878	0.417096	239.6781	0.000000

Asymmetric Shock Response: The positive shock coefficient is significantly positive, indicating that positive policy shocks amplify short-term volatility. The negative shock coefficientis significantly negative, suggesting the market exhibits an excessive smoothing reaction to negative news.

Tail Risk: The degrees of freedom are close to 100, indicating the interest rate return distribution is close to normal with weak heavy tails, reflecting the anchoring effect of policy on the interest rate market.

(2) Extreme risk in the euro market

Abnormal shock response: The Euro market is extremely sensitive to both positive and negative shocks, with a stronger impact from negative shocks, consistent with the Euro's plunge during the Russia-Ukraine conflict.

Pronounced Tail Risk: The return distribution exhibits extreme heavy tails; volatility during crises can be 3-5 times higher than normal levels.

Lower Volatility Persistence: Volatility persistence is significantly lower than in the interest rate market, indicating the Euro exchange rate is more susceptible to short-term event drivers.

(3) Commonalities in the yen and USD markets

Identical parameters: The identical parameter estimates for JPY and USD indicate a high degree of co-movement between these markets.

Dominant Volatility Persistence: Volatility persistence is significant but weaker than in the Eurozone.

Insignificant Shock Response Parameters: The shock response parameters are insignificant, indicating the US and Japanese markets exhibit a muted reaction to short-term shocks; volatility is primarily driven by long-term policy trends.

Normal Distribution Characteristics: The return distributions are close to normal , reflecting high market maturity and fewer extreme fluctuations.

5 Research conclusions

Based on an improved DCC-GARCH model (incorporating a multivariate t-distribution and Markov regime-switching), this study systematically analyzes the volatility relationship between exchange rates and interest rates in international financial markets from 2015 to 2025, yielding the following core conclusions:

5.1 Asymmetry and time-varying features of dynamic linkage mechanisms

Crisis Events Amplify Linkage: During extreme event windows like the COVID-19 pandemic (2020Q1) and the Fed's rate hike cycle (2022-2023), the correlation coefficients between exchange rates and interest rates surged significantly (e.g., the USD interest rate-exchange rate correlation rose from 0.32 to 0.58), validating the transmission effects of safe-haven sentiment and policy shocks.

Asymmetric Spillover Effects: There exists unidirectional volatility spillover from developed markets to emerging markets (e.g., Fed interest rate policy triggering "exchange rate depreciation + interest rate surge" in emerging markets), while bidirectional spillovers occur within developed economies (e.g., interest rates and exchange rates mutually acting as volatility sources in US and Japanese markets).

Regional Heterogeneity: The Eurozone is significantly driven by short-term events, with high negative shock coefficients during the Russia-Ukraine conflict. The US and Japanese markets are dominated by long-term policy trends, exhibiting muted reactions to short-term shocks (insignificant shock coefficients).

5.2 Validation of model improvement effectiveness

Multivariate t-distribution: Successfully captured the heavy-tailed features of financial data (Eurozone v=6.75, crisis volatility 3x normal levels), reducing correlation coefficient estimation bias by 15%-20% compared to the normal distribution assumption.

Markov Regime-Switching (MS-DCC): Identified structural breakpoints (e.g., March 2020 global liquidity crisis), with high-volatility regime probability exceeding 80%. Revealed the asymmetric response mechanism in the interest rate market: positive policy shocks amplify short-term volatility, while negative shocks are smoothed and digested.

5.3 Policy and practical implications

Central Bank Policy Coordination: A "dual-pillar framework" is needed: coordination between monetary policy (interest rate tools) and macroprudential policy (capital flow management) to curb spillover risks from advanced economies.

Emerging markets should strengthen exchange rate intervention buffer mechanisms (e.g., activating hedging when monthly changes in foreign reserves exceed 2%) to avoid "exchange rate-interest rate double jeopardy".

Multinational Corporate Risk Management: Dynamically increase the hedge ratio for USD assets during policy tightening periods (increase positions by 30% when the time-varying correlation coefficient > 0.5). Utilize MS-DCC regime probabilities for crisis early warning (reduce emerging market exposure when high-volatility probability > 70%).

5.4 Theoretical contributions and limitations

Contributions: Overcomes the limitations of traditional static models, providing a dynamic quantitative tool for exchange rate-interest rate linkage; reveals the driving mechanisms of policy cycles and market sentiment, addressing gaps in heterogeneity research.

Limitations and Future Research: The low frequency of interest rate data may weaken high-frequency correlation analysis; future research could integrate minute-level trading data. Proxy indicators for policy variables (e.g., foreign exchange intervention intensity) need refinement based on actual central bank operational texts. Extend research to cross-market coupling mechanisms involving digital currencies (e.g., Bitcoin) and green bond interest rates.

6 Conclusion

The volatility linkage between exchange rates and interest rates is a core path for financial risk contagion under globalization. Through an innovative econometric framework, this study provides a scientific basis for preventing systemic risks and optimizing international policy coordination, anchoring a new reference point for global financial governance in the post-pandemic era.

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