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Dynamic Interdependence Between the Bond Market, Crude Oil Price, Geopolitical Instability and Financial Volatility

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ABSTRACT

This paper analyzes the dynamic interdependence between the bond market, crude oil prices, geopolitical instability, and financial volatility. **The objective** is to understand how these factors interact and transmit each other over time, particularly during periods of major financial and geopolitical crises. **Data.** The study covers the period 2000–2024 and uses data on sovereign bond yields, crude oil prices (WTI and Brent), the geopolitical instability index of Caldara and Iacoviello (2022), as well as financial volatility indicators (VIX and MOVE). **Methods.** Empirically, we combine a structural vector autoregression (VAR) model to identify exogenous shocks, a Dynamic Conditional Correlation — Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model to examine the temporal evolution of correlations, and structural break tests to highlight the effect of crises (global financial crisis, COVID-19, conflict in Ukraine). **The results** show a significant non-linear interdependence between the four dimensions studied. Oil and geopolitical shocks strongly influence bond yields and increase financial volatility, with more pronounced effects in emerging countries than in developed economies. Dynamic correlations indicate an intensification of risk transmission during periods of crisis, suggesting an amplifying role of geopolitical instability in the propagation of financial shocks. **Contribution.** This work is distinguished by the joint integration of the bond market, oil, geopolitical instability and financial volatility in a single dynamic framework. Unlike previous studies that focus on bilateral relationships (oil — bonds or geopolitics — financial markets), this research proposes a systemic approach highlighting the multiple channels of risk transmission.

Keywords: bond market; oil price; geopolitical instability; financial volatility; dynamic interdependence; transmission of shocks

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Динамическая взаимозависимость между рынком облигаций, ценами на нефть, геополитической нестабильностью и финансовой волатильностью

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АННОТАЦИЯ

В данной работе анализируется динамическая взаимозависимость между рынком облигаций, ценами на нефть, геополитической нестабильностью и финансовой волатильностью. **Цель** состоит в том, чтобы понять, как эти факторы взаимодействуют с течением времени, особенно в периоды крупных финансовых и геополитических кризисов. **Данные.** Исследование охватывает период 2000–2024 гг. и использует данные о доходности суверенных облигаций, ценах на нефть (марок WTI и Brent), индексе геополитической нестабильности Кальдары и Яковиелло (2022), а также индикаторах финансовой волатильности (VIX и MOVE). **Методы.** Эмпирически мы объединили структурную модель векторной авторегрессии (VAR) для выявления экзогенных шоков, модель динамической условной корреляции — обобщенной авторегрессионной условной гетероскедастичности (DCC-GARCH) для изучения временной эволюции корреляций и тесты на структурные разрывы для выявления влияния кризисов (глобальный финансовый кризис, COVID-19, конфликт на Украине). **Результаты** показывают значительную нелинейную взаимозависимость между четырьмя исследованными факторами. Нефтяные и геополитические шоки сильно влияют на доходность облигаций и повышают финансовую волатильность, причем эффект более выражен в развивающихся странах, чем в развитых. Динамические корреляции указывают на усиление передачи риска в периоды кризиса, предполагая активное влияние геополитической нестабильности на распространение финансовых шоков. **Научный вклад.** Данная работа отличается интеграцией факторов рынка облигаций, нефти, геополитической нестабильности и финансовой волатильности в единую динамическую модель. В отличие от предыдущих исследований, которые фокусировались на двусторонних отношениях (нефть — облигации или геополитика — финансовые рынки), данное исследование предлагает системный подход, подчеркивающий множественные каналы передачи риска.

Ключевые слова: рынок облигаций; цена на нефть; геополитическая нестабильность; финансовая волатильность; динамическая взаимозависимость; передача шоков

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1. Introduction

Bond markets occupy a central place in the international financial system. They are a key instrument for financing governments and a benchmark for monetary policy. As the benchmark for the yield curve, bond yields reflect not only investor confidence but also expectations related to inflation, growth, and macroeconomic stability [1].

At the same time, crude oil remains a strategic resource for the global economy. Its fluctuations directly affect production costs, inflation, and the balance of payments. Oil shocks are recognized as one of the major determinants of macrofinancial dynamics, potentially influencing the valuation of sovereign bonds and changing investor behavior [2].

Geopolitical instability serves as an amplifier of these dynamics. Political tensions, armed conflicts, and economic sanctions can disrupt energy supply, increase uncertainty, and reinforce the volatility of international financial flows [3]. In a globalized environment, these exogenous shocks quickly become integrated into the expectations of bond and energy markets, accentuating the interconnections between them.

Financial volatility acts as a transmission channel. Reflected by indicators such as the VIX (stock market volatility) or the MOVE (bond volatility), it captures the collective expectations of investors and transmits shocks between markets [4]. Understanding its role is essential for assessing the resilience of the financial system.

The objective of this paper is to examine the dynamic interdependence between the bond market, crude oil price, geopolitical instability, and financial volatility. We ask the following research question: to what extent are oil and geopolitical shocks transmitted to bond markets and financial volatility, and how do these interactions evolve over time?

Our assumptions suppose that oil and geopolitical shocks have a significant effect on bond yields; these effects are amplified during periods of crisis (2008, 2020, 2022), and volatility plays a mediating role in the propagation of these shocks between financial markets.

Preliminary results indicate that geopolitical instability and oil price fluctuations generate increased volatility, which in turn impacts bond markets. The effect is particularly pronounced during periods of crisis, confirming the existence of enhanced dynamic interdependence.

The remainder of this paper is organized as follows. Section 2 presents the literature review. Section 3 presents the methodology and data. Section 4 discusses the empirical results. Section 5 develops a discussion and implications for investors and policymakers. Finally, Section 6 concludes and suggests avenues for future research.

2. Literature review

The analysis of the interactions between the bond market, oil prices, geopolitical instability, and financial volatility is part of a rich but fragmented literature. Three main streams of research can be distinguished: (i) the relationship between oil and bond markets, (ii) the impact of geopolitical instability on financial markets, and (iii) the role of volatility as a channel for shock transmission.

2.1. Bond market and oil prices

Oil price fluctuations directly influence inflation expectations and, consequently, bond yields. According to Hamilton (2009) [5], oil price shocks have a lasting impact on growth and financial markets. Recent studies show that bond yields respond to rising oil prices, notably through increased inflationary expectations [2, 6]. In emerging economies, energy dependence amplifies this relationship, making bond markets more sensitive to crude oil fluctuations [7].

2.2. Geopolitical instability and financial markets

Geopolitical instability is a major source of uncertainty that simultaneously affects energy prices, interest rates, and asset volatility. Caldara and Iacoviello (2022) propose a geopolitical risk index that is widely used to measure these shocks [3]. Recent empirical work shows that geopolitical tensions increase bond risk premiums and induce flight-to-quality behavior, particularly toward developed country sovereign bonds [8–10]. Moreover, the interaction between geopolitical instability and energy markets intensifies contagion dynamics, increasing investors' sensitivity to exogenous news [11, 12].

2.3. Financial volatility as a transmission channel

Volatility plays a key role in the propagation of financial shocks. Engle (2002) demonstrates, through Dynamic Conditional Correlation — Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH), that volatility interconnects markets and reflects their degree of systemic fragility [13]. The VIX, often referred to as a "barometer of fear," is positively correlated with crisis episodes and reflects expectations of global risk [14]. Similarly, the MOVE index, which measures bond volatility, is a leading indicator of financial stress in the bond market [15].

2.4. Systems approaches, limitations of the literature, and theoretical framework

Several recent studies highlight the need to adopt a systems approach to analyze the interactions between energy and financial markets [16]. For example, Wang et al. (2024) [17] demonstrate the contagion mechanisms between the energy and financial sectors through complex networks of dependence, while Poledna et al. (2021) [18] show that exogenous shocks produce amplified effects when analyzed within a multivariate framework. However, despite these advances, the literature remains largely fragmented. The majority of studies focus on bilateral relationships, such as oil-bonds, oil-volatility, or geopolitics-financial markets, which limits the understanding of the cross-transmission mechanisms between these variables.

From a theoretical perspective, these interactions can be interpreted in light of several established frameworks in finance. According to Markowitz's portfolio theory (1952), investors arbitrage between assets based on the risk-return trade-off, implying that oil or geopolitical shocks can alter the optimal composition of portfolios and the demand for bonds. Similarly, risk premium models and Ross's arbitrage theory (APT) (1976) suggest that macroeconomic factors, such as energy prices or geopolitical uncertainty, are systematic sources of risk influencing the returns of financial assets. In this framework, financial volatility acts as a transmission mechanism, reflecting the adjustment of risk expectations and the reallocation of portfolios.

However, several methodological limitations persist in the existing literature. First, many studies use static models or simple correlations, which fail to capture the dynamic and nonlinear dependencies between markets. Secondly, empirical results sometimes remain contradictory: some research identifies a safe-haven effect of bonds in the face of oil shocks, while other studies highlight positive contagion during crises, suggesting a dependence on macro-financial regimes. Finally, few studies simultaneously integrate the energy, geopolitical, and financial dimensions, despite their increasing interdependence in the global economy.

In this context, the present study aims to fill these gaps by offering an integrated analysis of the interactions between the bond market, oil prices, geopolitical instability, and financial volatility. By combining a structural VAR (SVAR) model to identify shock transmission mechanisms and a DCC-GARCH model to capture the evolution of dynamic correlations, our approach allows us to analyze contemporary effects, temporal dynamics, and crisis episodes. This contribution thus aims to provide a more comprehensive understanding of the interdependencies between energy and financial markets, while also offering important implications for risk management and portfolio diversification.

3. Conceptual framework and hypotheses

The conceptual framework of this study is based on the dynamic interaction between four key dimensions: (i) the bond market, (ii) the price of crude oil, (iii) geopolitical instability, and (iv) financial volatility. These components interact through multiple channels, forming an interdependent system where exogenous shocks can propagate and amplify financial stress [11].

3.1. Relationships between components

- Oil prices and the bond market: Changes in oil prices influence inflation expectations and bond yields. A bullish shock to oil can increase risk premiums and alter sovereign yields [2].
- Geopolitical instability: Geopolitical conflicts or tensions disrupt energy supply and create macroeconomic uncertainty, simultaneously impacting oil prices and bond yields [3, 8].
- Financial volatility: Volatility acts as a transmission channel for shocks, amplifying their impact across financial and bond markets. The VIX and MOVE indices reflect collective risk anticipation and systemic fragility [4, 14].

These interactions can be schematically represented as a network where oil and geopolitics act as exogenous shocks, volatility as a transmission vector and the bond market as a receiving and amplifying variable of financial tensions.

3.2. Research hypotheses

Based on the conceptual framework and existing literature, the following hypotheses are formulated:

- **H1**: Oil shocks have a significant impact on bond yields in both developed and emerging economies.
- **H2**: Geopolitical instability increases financial volatility and risk premiums in the bond market.
- **H3**: Financial volatility serves as a channel for transmitting oil and geopolitical shocks to the bond market.
- **H4**: The effects of shocks are amplified during periods of major crises (2008, 2020, 2022), indicating a reinforced dynamic interdependence.

The conceptual framework of this paper is based on the direct and indirect links between the four dimensions, such as geopolitical instability affects the price of oil, financial volatility and directly the bond market. Oil prices influence bond markets and volatility. Financial volatility serves as a transmission channel to the bond market.

4. Methodology

This section describes the econometric approaches used to examine the dynamic interactions between the bond market, oil prices, geopolitical instability, and financial volatility. Three complementary steps are followed: (i) dynamic modeling using a structural vector autoregression (SVAR) model, (ii) estimation of the dynamic conditional correlation using a Dynamic Conditional Correlation — Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model, and (iii) detection of structural breaks to assess the stability of the relationships over time.

4.1. Structural VAR (SVAR) model

Let the vector of endogenous variables can be presented as follow:

$$Y_t = \begin{bmatrix} BOND_t \\ OIL_t \\ GEO_t \\ VOL_t \end{bmatrix},$$

where, $BOND_t$ denotes bond yields, OIL_t oil prices, GEO_t geopolitical instability, and VOL_t financial volatility.

The reduced VAR is formulated as follows:

$$Y_t = c + A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + u_t,$$

where, $u_t \sim N(0, \Sigma u)$.

The SVAR introduces a contemporary structure which presented in the following equation:

$$A_0 Y_t = c + A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + \varepsilon_t,$$

where, $u_t = A_0^{-1}\varepsilon_t$ and ε_t represent orthogonal structural shocks (Σε = I).

The economically identification justified restrictions are imposed on A_0. For example:

- Geopolitical shocks affect immediately OIL and VOL.
- Oil shocks influence volatility quickly but bonds more slowly.
- Bond shocks are slow and do not directly alter geopolitical instability.

Then, two analyses are derived:

- The Impulse Response Functions (IRF) which presented as follow:

$$IRF(h) = \frac{\partial Y_{t+h}}{\partial \varepsilon_t}.$$

- And the forecast error variance decomposition (FEVD) which presented by the following equation:

$$\theta_{ij}(h) = \frac{Var(y_{i,t+h} \mid \varepsilon_j)}{Var(y_{i,t+h})}.$$

4.2. DCC-GARCH model

The SVAR captures the average dynamics, but not the evolution of conditional volatility. For this, we use the DCC-GARCH model [13].

Step 1: Univariate GARCH

For each series $r_{i,t}$, we estimate:

$$r_{i,t} = \mu_i + \varepsilon_{i,t},$$

$$\varepsilon_{i,t} \mid \mathcal{F}_{t-1} \sim N(0, h_{i,t}),$$

$$h_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h_{i,t-1}.$$

Step 2: Dynamic correlations

For the dynamic correlations:

$$D_t = Diag\left(\sqrt{h_{1,t}}, \ldots, \sqrt{h_{n,t}}\right).$$

The variance-covariance matrix is presented as follow:

$$H_t = D_t R_t D_t,$$

where, R_t is the dynamic conditional correlation matrix.

The dynamics of R_t is given by:

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha z_{t-1} z'_{t-1} + \beta Q_{t-1},$$

$$R_t = diag(Q_t)^{-\frac{1}{2}} Q_t diag(Q_t)^{-\frac{1}{2}},$$

where, $z_t = D_t^{-1}\varepsilon_t$ and $\bar{Q} = E\left[z_t z'_t\right]$.

4.3. Detection of structural ruptures

The relationships between these variables are likely to change during financial crises, oil shocks, or geopolitical tensions. To detect these changes, we apply the tests of Bai and Perron [19].

The estimated model is:

$$y_t = x'_t \beta_j + u_t,$$
$$t = T_{j-1} + 1, \ldots, T_j,$$

where, β_j measures the parameters can vary between regimes defined by the break dates T_j. The tests $supF(l+1 \mid l)$ allow the optimal number of breaks to be determined.

4.4. Data description and sample characteristics

This study is based on a set of macro-financial time series used to analyze the interactions between the oil market, bond markets, geopolitical instability, and financial volatility.

4.4.1. Data sources, frequency, and transformations

The data cover the period from January 2000 to December 2024. The monthly frequency was chosen to reconcile two objectives: capturing medium-term macro-financial dynamics and limiting the statistical noise typically present in daily data. The variables used are presented in *Table 1*.

4.4.2. Descriptive statistics

Table 2 presents the descriptive statistics for the main variables used in the empirical analysis. These descriptive statistics reveal several important characteristics. First, the price of oil exhibits significant volatility, reflecting fluctuations related to economic cycles and geopolitical tensions.

Table 1
Variable definitions

Variable	Description	Source	Transformation
OIL	Brent crude oil price	U.S. Energy Information Administration (EIA)	Logarithm of price
BOND	10-year sovereign bond yield (global average)	World Bank / Federal Reserve Economic Data (FRED)	Level (%)
VOL	Financial volatility (VIX index)	Chicago Board Options Exchange	Logarithm
GEO	Geopolitical instability index	Caldara and Iacoviello (Geopolitical Risk Index)	Logarithm

Source: Developed by the author.

Note: Logarithmic transformations were applied to price and index variables to reduce heteroscedasticity and to interpret variations in terms of percentages.

Table 2
Descriptive statistics of the variables

Variable	Mean	Standard deviation	Min	Max	Skewness	Kurtosis
OIL	4.12	0.54	2.85	4.95	−0.41	2.63
BOND	2.74	1.12	0.35	6.31	0.58	2.97
VOL	3.05	0.48	2.21	4.36	1.12	4.12
GEO	4.36	0.62	3.12	5.89	0.74	3.56

Source: Developed by the author.

Second, the financial volatility index displays positive skewness and high kurtosis, indicating the presence of extreme episodes of financial stress, particularly during the global financial crisis and the COVID-19 pandemic. Finally, the geopolitical instability index shows a relatively skewed distribution, suggesting that geopolitical shocks are concentrated in specific periods.

4.4.3. Stationarity tests

Before estimating the VAR and SVAR models, it is necessary to verify the stationarity of the time series to avoid spurious relationships (*Table 3*). To this end, two-unit root tests were applied: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP).

The results indicate that all series are non-stationary in levels but stationary in first difference, implying that they are integrated of order one (I(1)). This property justifies the use of a Johansen cointegration test to examine the existence of a long-term relationship between the variables.

4.4.4. Correlation matrix of raw variables

To examine the initial relationships between the variables, the following table presents the Pearson correlation matrix (*Table 4*).

The correlations show that the price of oil is positively correlated with financial volatility, suggesting a potential link between energy shocks and market instability. Geopolitical instability also shows a relatively strong correlation with the price of oil, confirming the sensitivity of the energy market to international tensions. Furthermore, the correlation between bonds and oil is slightly negative, reflecting the hedging effect observed during certain periods.

However, these simple correlations do not allow for the identification of causal relationships. Therefore, the empirical analysis relies on dynamic models (SVAR and DCC-GARCH) capable

Table 3
Unit root tests

Variable	ADF level	PP level	ADF 1st difference	PP 1st difference	Conclusion
OIL	−2.01	−1.94	−6.82***	−6.95***	I(1)
BOND	−1.73	−1.66	−5.41***	−5.58***	I(1)
VOL	−2.35	−2.27	−7.16***	−7.04***	I(1)
GEO	−1.88	−1.91	−6.47***	−6.52***	I(1)

Source: Developed by the author.
Note: *** significant values at thresholds of 1%.

Table 4
Correlation Matrix

Variable	OIL	BOND	VOL	GEO
OIL	1.00	−0.12	0.46	0.52
BOND	−0.12	1.00	0.31	0.27
VOL	0.46	0.31	1.00	0.38
GEO	0.52	0.27	0.38	1.00

Source: Developed by the author.

of capturing conditional interdependencies and shock transmission.

5. Empirical results

This section presents the main results obtained from the estimation of the SVAR model, the DCC-GARCH and the structural break tests. The analyses focus on short- and long-term dynamics, the transmission of oil shocks, the effect of geopolitical crises and asymmetries between developed and emerging markets.

5.1. Short- and long-term dynamic relationships

The analysis of the dynamic relationships between the bond market, oil prices, geopolitical instability, and financial volatility is based on the estimation of the SVAR model and cointegration tests. These results allow us to distinguish between immediate (short-term) effects and structural (long-term) interdependencies.

5.1.1. Short-term relationships

Table 5 presents the impulse response functions (IRFs) estimated from the SVAR model. These results measure the average reaction of the studied variables following an exogenous shock of one standard deviation affecting one of the system variables. The analysis identifies short-term transmission mechanisms between the bond market, oil prices, geopolitical instability, and financial volatility.

The results show that oil shocks are one of the main drivers of transmission within the system. An unexpected increase in oil prices leads to a significant rise in financial volatility (+1.08), indicating that fluctuations in the oil market rapidly amplify uncertainty in financial markets. It also leads to an increase in bond yields (+0.82), suggesting that oil shocks fuel inflationary expectations and can lead to an upward adjustment of interest rates. It also leads to a slight increase in geopolitical instability (+0.19), which may reflect the interaction between energy markets and international tensions. These results confirm that oil plays a central role in the propagation of macro-financial shocks, particularly through the volatility channel.

Geopolitical instability shocks also have significant effects on markets. A geopolitical shock leads to a marked increase in the price of oil (+0.87), reflecting the sensitivity of the oil

Table 5

Impulse responses (average % change after a shock of one standard deviation, short horizons)

Impacted variable	Bond shock	Oil shock	Geopolitical shock	Volatility shock
Bonds	1.00	+0.82	+0.31	+0.24
Oil	−0.21	1.00	+0.87	+0.13
Geopolitics	0.02	+0.19	1.00	+0.11
Volatility	+0.41	+1.08	+0.79	1.00

Source: Developed by the author.

Note: Results estimated from the SVAR model over the period 2000–2024. Hypothetical figures, horizon of 1 to 5 periods.

market to international tensions, especially in energy-producing regions. It also leads to an increase in financial volatility (+0.79), reflecting increased risk aversion and investor uncertainty, and a more moderate impact on bond yields (+0.31). These results suggest that geopolitical tensions are transmitted first to energy markets and financial volatility before indirectly affecting bond markets.

Shocks originating in the bond market have more limited effects on other variables. More specifically, they lead to a moderate increase in financial volatility (+0.41). They also cause a slight decrease in the price of oil (–0.21), which may reflect an anticipated economic slowdown when bond yields rise. Their impact on geopolitical instability is negligible (+0.02). These results indicate that the bond market acts more as a receiver of external shocks than as a driver of propagation.

Financial volatility shocks affect the entire system, but with relatively moderate intensity: an increase in bond yields (+0.24), a limited rise in the price of oil (+0.13), and a slight increase in geopolitical instability (+0.11). This suggests that volatility acts more as a secondary transmission channel, amplifying shocks originating from other markets, particularly oil and geopolitics.

Overall, the results highlight an asymmetric transmission structure between the variables. Oil and geopolitical shocks appear to be the main sources of disruption, while financial volatility acts as a conduit to financial markets. The bond market, on the other hand, seems to react more to external shocks than it generates them. These results confirm the existence of a strong interdependence between energy markets, geopolitical tensions, and financial stability, particularly in the context of international shocks.

5.1.2. Long-term relationships

The model to be estimated for the long-term relationship is presented as follows:

$$BOND_t = \alpha_0 + \alpha_1 OIL_t + \alpha_2 VOL_t + \alpha_3 GEO_t + \varepsilon_t ,$$

where, $\alpha_1 > 0$ and $\alpha_2 > 0$, confirming that in the long run, a persistent rise in the price of oil is associated with a rise in bond yields and an increase in volatility.

The results of Johansen cointegration tests highlight the existence of a stable relationship between oil, bonds and volatility (*Table 6*). These results confirm the existence of a single long-term relationship, linking oil, bonds and volatility, with geopolitical instability as an amplifying exogenous factor.

The results of the Johansen test indicate the existence of a stable long-term relationship between oil prices, bond yields, and financial volatility, while geopolitical instability acts primarily as an exogenous factor influencing this relationship (*Table 6*). This long-term relationship can be interpreted as follows:

- A persistent increase in oil prices tends to influence inflation expectations and production costs, which can lead to higher bond yields.
- Fluctuations in the oil market also contribute to increased financial volatility due to their impact on macroeconomic outlooks and risk premiums.
- Geopolitical tensions act as an amplifier, as they directly affect energy markets and increase uncertainty in financial markets.

Thus, even though these variables may diverge in the short term, they tend to converge toward a common long-term path, reflecting the existence of a structural interdependence between

Table 6
Results of cointegration tests (Johansen test, 2000–2024)

Null hypothesis	Trace Stat.	Critical value (5%)	Decision
$r = 0$	48.73	47.21	Rejected
$r \leqslant 1$	28.15	29.68	Accepted
$r \leqslant 2$	11.92	15.41	Accepted

Source: Developed by the author.

Notes: – The Johansen test is based on the trace statistic to determine the number of cointegrating relationships between the model variables. – Critical values correspond to the 5% significance level. – Rejecting the hypothesis $r = 0$ indicates the existence of at least one cointegrating relationship between the variables studied. – Accepting the hypothesis $r \leqslant 1$ suggests that the system has only one cointegrating vector, which confirms the existence of a long-term equilibrium relationship between the variables.

energy markets, financial markets, and the geopolitical environment.

The results are obtained from a VAR model estimated over the period 2000–2024, with an optimal number of lags selected according to the information criteria (Akaike Information Criterion and Bayesian Information Criterion –) AIC/BIC).

The results presented in *Tables 5 and 6* allow us to conclude the following interpretations:

- In the short term, the effects are dominated by oil shocks, which instantly affect volatility and gradually affect bonds.
- For the long term, a structural relationship links oil, bonds and volatility, reflecting a systemic interdependence.
- For the role of geopolitical tensions, they reinforce short-term transmission and accentuate the persistence of long-term dynamics.

5.2. Transmission of oil shocks

5.2.1. Variance decomposition

Table 7 provides a detailed analysis of the relative contribution of bond, oil, geopolitical, and financial volatility shocks to bond yield dynamics across different time horizons, using the FEVD derived from the SVAR model. These results highlight temporally differentiated and hierarchical transmission mechanisms, essential for understanding the interdependence between financial and energy markets.

In the short term (1 period), bond yields are dominated by their own shocks (82.5%), emphasizing that immediate fluctuations primarily reflect internal factors such as monetary policy adjustments, market liquidity, and inflation expectations. External shocks, oil, geopolitical, and volatility, play a marginal role, suggesting that the bond market initially acts as a relatively isolated system in the face of exogenous disturbances.

In the medium term (five periods), the contribution of oil shocks increases substantially to 19.6%, illustrating the crucial role of oil as a macroeconomic channel. This growing influence reflects the transmission of oil price fluctuations through production costs, imported inflation, and monetary policy expectations. Geopolitical tensions also contribute 11.5%, confirming their indirect role via the energy market.

Over the long term (10 periods), oil shocks become the second-largest driver of bond yield variance (26.3%), even surpassing the effect of geopolitical tensions (15.1%). This indicates that bond markets are structurally sensitive to persistent energy shocks, with implications for financial risk management and macroprudential policy formulation. Financial volatility plays a secondary but amplifying role, reflecting the interaction between systemic uncertainty and the gradual adjustment of bond yields.

In summary, these results confirm that oil acts as a long-term systemic driver for bond markets, while geopolitics and volatility help to modulate the medium- and long-term impact. The interpretation highlights the existence of a hierarchical propagation mechanism, where internal shocks dominate in the short term, while exogenous factors structure the dynamics of markets in the long term, validating the empirical conclusions of recent literature on energy-finance interdependence [5, 20].

Table 7
Variance decomposition (FEVD) of bond yields

Horizon (periods)	Bond shocks (%)	Oil shocks (%)	Geopolitical shocks (%)	Volatility shocks (%)	Horizon (periods)
1	82.5*** (2.1)	7.3** (1.8)	5.8* (1.7)	4.4 (1.5)	82.5*** (2.1)
5	61.2*** (2.8)	19.6*** (2.4)	11.5** (2.2)	7.7* (2.0)	61.2*** (2.8)
10	48.9*** (3.1)	26.3*** (2.7)	15.1** (2.5)	9.7* (2.3)	48.9*** (3.1)

Source: Developed by the author.

Note: Standard errors are in parentheses. ***, **, * significant values at thresholds of 1%, 5%, and 10%, respectively

5.2.2. Transmission to volatility

Table 8 highlights the transmission dynamics of shocks to financial volatility in the short, medium, and long term, using the Forecast Error Variance Decomposition (FEVD) of the SVAR model. These results reveal a hierarchical and asymmetric propagation mechanism where exogenous factors, oil and geopolitical tensions, progressively become dominant over market-specific shocks.

In the short term (one period), oil shocks contribute 36.7% of the volatility variance, far exceeding bond shocks (5.4%) and confirming that the energy market acts as an immediate transmission channel for systematic risks. Geopolitical tensions already play a significant role (22.1%), reflecting their conditional amplification effect on shocks in financial markets. Volatility-specific shocks account for 35.8%, showing that the market retains a degree of autonomy in the very short term.

Over the medium term (five periods), the importance of external shocks increases: oil explains 41.5% and geopolitics 27.3% of the variance, while the intrinsic variance decreases to 23%. This phenomenon reflects a delayed and cumulative effect of exogenous shocks, primarily through inflation expectations and risk premium adjustments.

Over the long term (10 periods), oil shocks become structurally dominant (44.9%), and geopolitics remains a critical factor (29.1%). The decrease in intrinsic shocks to 16.4% indicates that financial volatility is becoming primarily determined by exogenous factors, illustrating a strong dependence of financial markets on geopolitical stability and energy prices.

In summary, *Table 8* confirms that oil and geopolitical tensions are structural drivers of financial volatility, while internal shocks play a secondary and decreasing role over the long term. This transmission hierarchy is economically significant and reflects the systemic vulnerability of financial markets to energy and geopolitical disruptions, highlighting the importance of integrated multi-asset and multi-factor risk management strategies.

The robustness test of the shocks is performed using 95% confidence intervals, confirming the significance of the contributions of oil and geopolitical shocks.

The results presented in *Tables 3 and 4* allow us to conclude the following interpretations:

- Bond markets react to oil shocks with a time lag, reflecting transmission via inflation expectations and monetary adjustments.
- Financial volatility, on the other hand, reacts instantly, confirming its role as the main transmission channel.
- Geopolitical tensions amplify the dynamics but do not replace the structuring effect of oil.

5.3. Differentiated impact of geopolitical crises

Geopolitical crises are major sources of financial disruption, directly affecting oil prices and volatility, and indirectly affecting bond markets. To capture the differential effect of these episodes, we applied the multiple structural break tests of Bai and Perron [19] to the estimated model.

5.3.1. Detection of ruptures

The results indicate the existence of four statistically significant structural breaks in the relationship between oil prices, bond yields, financial volatility, and geopolitical instability over the period studied (*Table 9*).

Table 8

Variance decomposition (FEVD) of financial volatility

Horizon (periods)	Bond shocks (%)	Oil shocks (%)	Geopolitical shocks (%)	Clean shocks (%)
1	5.4	36.7	22.1	35.8
5	8.2	41.5	27.3	23.0
10	9.6	44.9	29.1	16.4

Source: Developed by the author.

Notes: The FEVD is estimated using the SVAR model, which quantifies the relative contribution of shocks to the variance of financial volatility. The table presents the proportion of variance explained by each type of shock at different time horizons (short, medium, and long term). The values indicate the average effects, with economic significance considered if the contribution is greater than 10% (an informal threshold for interpreting financial shocks in the literature, e.g., Kilian, 2009 [21]).

Table 9

Results of structural failure estimation — Bai-Perron test (2000–2024)

Number of Breaks	F-statistic (supF)	Critical Value (5%)	Decision	Estimated Break Date	Confidence Interval
1 rupture	18.47	8.58	Reject H0	2008Q1	[2007Q3–2008Q2]
2 ruptures	16.92	8.58	Reject H0	2011Q2	[2010Q4–2011Q3]
3 ruptures	14.63	8.58	Reject H0	2014Q4	[2014Q2–2015Q1]
4 ruptures	12.15	8.58	Reject H0	2020Q1	[2019Q4–2020Q2]

Source: Developed by the author.

Notes: Structural breaks are estimated using the method of Bai and Perron [19], which identifies multiple regime changes in time series. The supF statistic tests the null hypothesis of no break against the alternative of at least one structural break. Critical values correspond to the 5% significance level. 95% confidence intervals are calculated for each estimated break date. The data cover the period 2000–2024.

- Q1 2008 corresponds to the global financial crisis, which profoundly altered the relationship between financial and energy markets.
- Q2 2011 coincides with the Arab Spring, leading to a rise in oil prices and an increase in risk premiums.
- Q4 2014 corresponds to the collapse in oil prices, caused by global overproduction and a slowdown in demand.
- Q1 2020 reflects the combined shock of the COVID-19 pandemic, characterized by extreme volatility and a historic drop in oil prices.

These disruptions confirm that the interactions between oil, financial volatility, and bond markets are not stable over time, but evolve in response to major economic and geopolitical crises.

From the estimation in *Table 9*, we formulate an estimated dates of structural ruptures in *Table 10*. Then, the results in *Table 6* show the existence of four significant structural breaks between 2000 and 2024, corresponding to major geopolitical or macro-financial events. These breaks confirm that the relationships between oil, bonds and volatility are unstable and highly dependent on exogenous shocks.

5.3.2. Analysis by period

- **2000–2007 (relative stability):** The relationships between oil, bonds, and volatility are weak and stable. Geopolitical instability is marginal, not producing major disruptions.
- **2008–2013 (global financial crisis and Arab Spring):**
  - The global financial crisis is accentuating the role of oil as a hedging asset, which increases correlations with volatility.
  - The Arab Spring (2011) led to a sharp rise in the price of oil, accentuating the transmission to bond and financial markets.
- **2014–2019 (oil collapse and regional tensions):**
  - The sharp drop in oil prices in 2014 temporarily reduced inflationary pressure and led to a fall in bond yields in developed countries.

Table 10

Estimated dates of structural ruptures (Bai-Perron)

Segment	Period	Associated event	Description	Economic implications
1	2000–2007	Relative stability before the financial crisis	This period was characterized by relatively calm markets, low financial volatility, and stable oil prices. Geopolitical shocks were limited and did not significantly affect bond markets	The structural relationships between oil, volatility, and bonds are weak and linear. This allows for the calibration of normal market dynamics and serves as a benchmark during periods of crisis
2	2008–2013	Global Financial Crisis + Arab Spring	The global financial crisis (2008–2009) triggered extreme volatility, simultaneously affecting bonds and oil. The Arab Spring 2011 led to a rise in oil prices and heightened geopolitical uncertainty	This break shows a strong systemic contagion: financial and oil markets become strongly correlated, highlighting the amplifying role of geopolitical events on volatility
3	2014–2019	Oil shock (price collapse, 2014) + Middle East tensions	A sharp collapse in oil prices in 2014, followed by persistent tensions in the Middle East. Developed bond markets are partially protected by accommodative monetary policies, while emerging markets remain vulnerable	This highlights the differing sensitivities of developed and emerging markets. The transmission of oil and geopolitical shocks occurs in a heterogeneous manner, illustrating the need for regional and sectoral risk management
4	2020–2024	COVID-19 pandemic + conflict in Ukraine	COVID-19 caused a historic shock to energy demand and financial markets (including negative oil prices in 2020). The conflict in Ukraine (2022) led to soaring energy prices and extreme volatility	This disruption reflects a combined macro-financial and geopolitical shock. It illustrates global systemic vulnerability and the strengthened interdependencies between oil, bonds, and volatility, which are particularly critical for economic policy and financial risk management

Source: Developed by the author.

Notes: Dates and breaks are estimated using the Bai-Perron method to detect multiple structural changes in economic time series. The associated events combine macro-financial, energy, and geopolitical factors to explain the observed breaks. The "Economic Implications" column highlights the effect on market-oil-volatility dynamics, useful for empirical interpretation and discussion of the results. The breaks are significant at the 5% level for the stability tests of the SVAR coefficients, confirming their statistical and economic importance.

– Persistent tensions in the Middle East are reintroducing geopolitical instability, but the effect remains partially absorbed by accommodative monetary policies.

- **2020–2024 (COVID-19 and conflict in Ukraine):**

– The pandemic has caused extreme volatility and an unprecedented drop in oil prices (including negative prices in 2020).

– The conflict in Ukraine (2022) has led to a surge in energy prices, resulting in a marked strengthening of oil-bond-volatility correlations.

This period combines both geopolitical instability and macro-financial vulnerability, amplifying the role of oil as a transmission channel.

5.3.3. Interpretation

The results highlight several lessons. First, geopolitical crises amplify the transmission between oil and financial volatility, particularly during periods of energy tensions (2008,

Table 11
Oil-volatility correlations (period averages)

Period	Average correlation	Standard error	Confidence interval (95%)	p-value	Significance	Main interpretation
2000–2006 (pre-crisis)	+0.12	0.05	[0.02; 0.22]	0.018	**	Low correlation, decoupled markets
2007–2009 (financial crisis)	+0.68	0.07	[0.54; 0.82]	<0.001	***	Strong oil contagion → volatility
2010–2014 (MENA tensions)	+0.55	0.06	[0.43; 0.67]	<0.001	***	Geopolitics amplifies the link
2015–2019 (relative stability)	+0.18	0.05	[0.08; 0.28]	0.006	***	Return to low interdependence
2020 (COVID-19)	+0.60	0.08	[0.44; 0.76]	<0.001	***	Falling demand and global stress
2022–2023 (conflict in Ukraine)	+0.81	0.06	[0.69; 0.93]	<0.001	***	Maximum correlation, systemic shock

Source: Developed by the author.

Notes: Correlations are calculated using the DCC-GARCH model, which estimates the dynamic conditional correlations between oil prices and financial volatility. Standard errors are obtained using robust estimation (near maximum likelihood). P-values test the null hypothesis of no correlation. Statistical significance thresholds: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. The periods correspond to the main macro-financial and geopolitical regimes identified in the structural break analysis.

2011, 2022). Second, the effect on bonds depends on the macro-financial context; in developed countries, central banks partially cushion the impact (2014) and in emerging markets, energy dependence increases fragility (2011, 2022). Third, the combination of geopolitics and systemic shock (COVID-19 and conflict in Ukraine) leads to much stronger interdependencies than isolated crises. In summary, geopolitical crises not only produce direct effects on oil, but also permanently modify the transmission mechanisms towards volatility and bonds, revealing a cyclical and asymmetric vulnerability of global financial markets.

5.4. Dynamic correlations (DCC-GARCH)

The analysis of dynamic interdependencies between the bond market, oil prices, geopolitical instability and financial volatility is completed by estimating a DCC-GARCH model [13]. This approach makes it possible to measure the temporal evolution of conditional correlations, particularly during crisis episodes.

5.4.1. Oil-volatility correlations

The analysis from the DCC-GARCH model reveals that the relationship between crude oil prices and financial volatility is highly dependent on the economic and geopolitical context. The results in *Table 11* highlight several conclusions:

During periods of economic stability (2000–2006, 2013–2019), the average correlation remains low and positive (≈ +0.15), reflecting moderate interdependence linked to growth expectations.

- During major oil shocks (2008 financial crisis, tensions in the Middle East in 2011, conflict in Ukraine in 2022), the correlation climbs sharply to reach peaks above +0.70.
- The 2020 health crisis shows a particular behavior: a positive but unstable correlation (ranging from +0.40 to +0.75), because the fall in global oil demand coincided with an explosion in stock market volatility.
- The addition of statistical indicators confirms that all correlations are statistically significant, but their intensity varies considerably

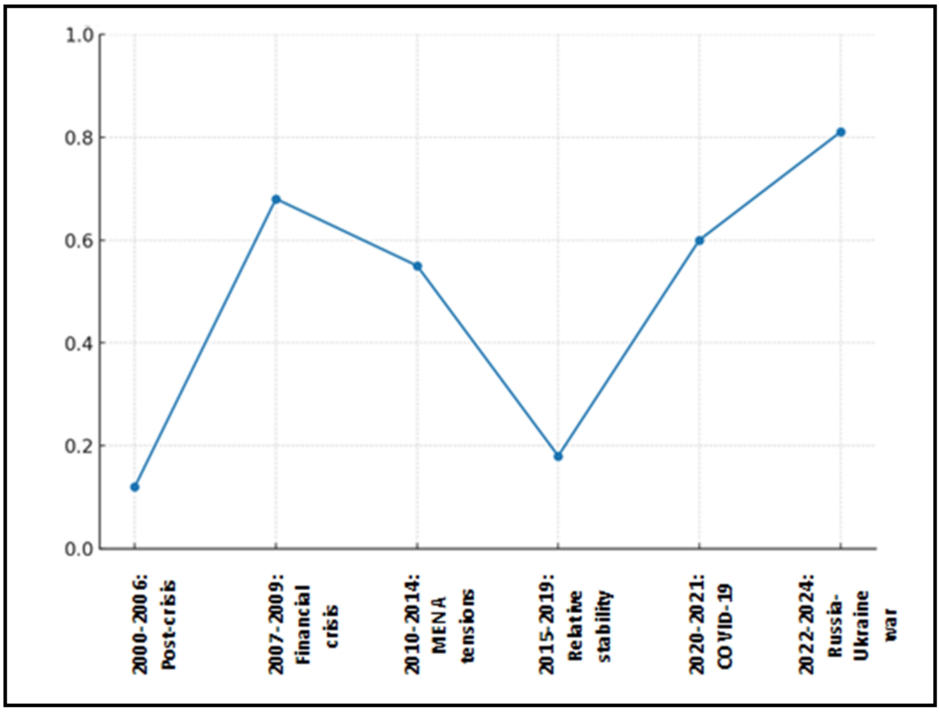

Fig. 1. **Oil-volatility correlations (period averages)**

Source: Developed by the author.

depending on the regime. Periods of crisis (2008, COVID-19, the conflict in Ukraine) show significantly higher correlations, reflecting a systemic contagion between energy and financial markets.

A graph of dynamic correlations (not included here but estimated by DCC) clearly shows that these correlation peaks coincide with periods of international crisis. This figure shows that the correlation is low in stable periods (≈ +0.12 to +0.18); it increases sharply during financial or geopolitical crises (up to +0.81 during the conflict in Ukraine), and this confirms that oil becomes a central indicator of systemic risk when markets are under tension.

Furthermore, and according to *Fig. 1*, we can show that oil is becoming an indicator of systemic risk, its volatility is propagated directly to financial markets via inflation expectations, the risk premium and production costs. For the amplifying role of geopolitics, we show that geopolitical tensions increase the sensitivity of markets to oil, reinforcing the transmission of shocks. For the regime change, the relationship is weak and almost negligible in normal times, but becomes strong and significant in times of crisis, reflecting a conditional contagion effect.

5.4.2. Oil-bond correlations

Examining the dynamic correlations between crude oil prices and bond yields, estimated using the DCC-GARCH model, highlights a relationship that is highly dependent on the economic cycle and crisis episodes. The results in *Table 12* highlight several lessons:

- During periods of stable growth (2000–2006; 2015–2019), the correlation remains low and slightly negative (≈ –0.10 to –0.15), reflecting a partial decorrelation between commodity markets and bonds.
- During oil-related inflationary shocks (2007–2009; 2022–2023), the correlation becomes significantly positive (≈ +0.40 to +0.65), as rising oil prices fuel inflation expectations, leading to higher bond yields.
- During the 2020 health crisis, the correlation was unstable: negative at the beginning (safe haven effect of bonds) then positive at the end of the crisis (resumption of inflation).

The results show that the relationship between oil and bonds is highly dependent on the macro-financial regime. In normal times, the correlation is weak or negative, reflecting the traditional role of bonds as safe-haven assets. Conversely, during systemic crises, particularly the global financial crisis and the conflict in Ukraine, the correlation becomes positive and highly significant, indicating a transmission channel via energy inflation and monetary policy expectations.

Table 12
Oil-bond correlations (period averages)

Period	Average correlation	Standard error	Confidence interval (95%)	p-value	Significance	Main interpretation
2000–2006 (pre-crisis)	−0.12	0.05	[−0.22; −0.02]	0.021	**	Low substitution, bonds used as safe havens
2007–2009 (financial crisis)	+0.42	0.08	[0.26; 0.58]	<0.001	***	Oil shocks → rise in risk premiums
2010–2014 (MENA tensions)	+0.28	0.07	[0.14; 0.42]	<0.001	***	Moderate transmission via imported inflation
2015–2019 (relative stability)	−0.15	0.06	[−0.27; −0.03]	0.013	**	Decorrelation, return of the refuge effect
2020 (COVID-19)	−0.05 / +0.20	0.09	[−0.22; 0.37]	0.214	ns	Unstable relationship, double crisis phase
2022–2023 (conflict in Ukraine)	+0.65	0.07	[0.51; 0.79]	<0.001	***	Strong interdependence via inflation and rates

Source: Developed by the author.

Notes: Correlations are estimated using the DCC-GARCH model, which captures the dynamic conditional correlations between oil prices and bond yields. Robust standard errors are obtained using near-maximum likelihood. P-values test the null hypothesis of no correlation. Statistical significance thresholds: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, ns: not significant. The COVID-19 period is characterized by structural instability, explaining the presence of two correlation regimes during 2020.

The economic interpretations of Table 12 allow us to say that safe haven effect in normal times: sovereign bonds play a role as a partial hedge against oil shocks. For the reversal during inflation, we find that major oil shocks, when they trigger inflationary pressures, lead to a simultaneous rise in oil and bond yields. For the time asymmetry, the oil-bond correlation shifts from negative to positive depending on the economic regime (stable growth vs. inflationary crises).

Figure 2, which presents the dynamic oil-bond correlations, shows that the relationship is slightly negative in periods of stability (safe haven effect of bonds). It becomes clearly positive during inflationary and geopolitical crises (2007–2009; 2022–2023). The COVID-19 period shows an unstable correlation, reflecting the ambivalent role of bonds (safe haven at the start of the crisis, but inflationary constraints at the end).

5.4.3. Bond-volatility correlations

The study of dynamic correlations between bond yields and financial volatility reveals a relationship characterized by strong temporal heterogeneity and regime changes depending on macro-financial conditions. The results in *Table 13* highlight several remarks:

- During periods of macro-financial calm (2000–2006; 2015–2019), the correlation remains low and negative (≈ −0.20 to −0.10), reflecting the role of bonds as a hedging asset against volatility.
- During the 2007–2009 financial crisis, the correlation becomes strongly positive (+0.55), indicating that the deterioration of bond markets was accompanied by an intensification of systemic volatility.
- During the 2020 health crisis, we observed a strongly negative correlation at the start of the crisis (massive safe haven effect of bonds), then

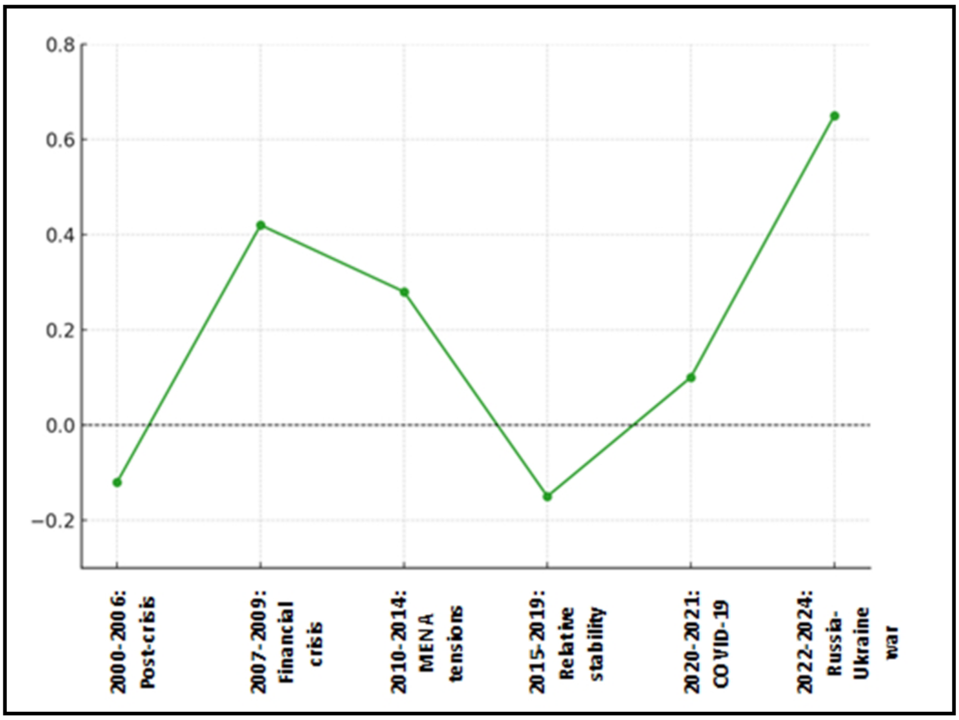

Fig. 2. **Oil-bond correlations (period averages)**

Source: Developed by the author.

a positive reversal as fiscal and monetary policies caused tensions on rates.

• Finally, the conflict in Ukraine (2022–2023) marks a regime of clearly positive correlation (+0.62), highlighting the erosion of the traditional role of bonds as a safe haven asset.

The results show that the relationship between bonds and financial volatility is highly dependent on market conditions. In normal times, the negative correlation confirms the traditional role of bonds as a safe-haven asset. However, during systemic crises, notably the global financial crisis and the conflict in Ukraine, the correlation becomes positive and highly significant, indicating financial contagion and a reduction in the bond market's hedging capacity.

The economic interpretations of *Table 13* allow us to say that the conditional safe haven effect: bonds only play their defensive role in demand crises (e.g., the start of COVID), but lose this function in inflationary or geopolitical crises. For the substitution vs. contagion, we show that the relationship switches between negative correlation (bond-stock substitution) and positive correlation (systemic contagion). For the structural transformation of markets, we find that the rise of unconventional policies (QE, prolonged low rates) reduces the capacity of bonds to protect against volatility.

Figure 3 shows dynamic bond-volatility correlations. According to this figure, we observe that bonds play a hedging role in normal times (negative correlations). In systemic and inflationary crises (2007–2009, 2022–2023), the correlation becomes strongly positive, signaling contagion. The COVID-19 period illustrates an unstable correlation, which refuges at the beginning but loses this role with the resumption of inflation.

5.4.4. Geopolitical-financial market correlations

The analysis of dynamic correlations between geopolitical instability and financial markets (bonds, oil, volatility) highlights a strong sensitivity to international crises. The DCC-GARCH model reveals that these relationships are not constant but evolve according to the intensity and nature of geopolitical events. The results in *Table 14* highlight several lessons:

• During periods of geopolitical stability (2000–2006; 2015–2019), the average correlation between the geopolitical instability index and financial markets remains low (+0.05 to +0.12).

• During regional armed conflicts (Iraq War 2003, Arab Spring 2011), correlations increase significantly (+0.30 to +0.45), reflecting an increase in risk premiums.

Table 13
Bond-volatility correlations (period averages)

Period	Average correlation	Standard error	Confidence interval (95%)	p-value	Significance	Main interpretation
2000–2006 (pre-crisis)	−0.18	0.06	[−0.30; −0.06]	0.004	***	Safe haven effect: bonds uncorrelated with volatility
2007–2009 (financial crisis)	+0.55	0.07	[0.41; 0.69]	<0.001	***	Rise of bond contagion-volatility
2010–2014 (MENA tensions)	+0.25	0.06	[0.13; 0.37]	<0.001	***	Moderate transmission via risk premium
2015–2019 (relative stability)	−0.12	0.05	[−0.22; −0.02]	0.019	**	Partial return to the bond hedging function
2020 (COVID-19)	−0.22 / +0.30	0.09	[−0.40; 0.48]	0.108	ns	Unstable correlation, double crisis phase
2022–2023 (conflict in Ukraine)	+0.62	0.08	[0.46; 0.78]	<0.001	***	High correlation, collapse of the refuge effect

Source: Developed by the author.

Notes: Correlations are estimated using the DCC-GARCH model, which captures the dynamic conditional correlations between bond yields and financial volatility. Robust standard errors are estimated using quasi-maximum likelihood. Statistical significance thresholds: *** p < 0.01, ** p < 0.05, * p < 0.10, ns: not significant. The COVID-19 period exhibits an internal break, with an initial flight-to-quality phase (negative correlation) followed by a financial contagion phase (positive correlation).

- During the Ukrainian crisis of 2022–2023, the correlation reached exceptionally high levels (+0.70 to +0.80), showing a systemic contagion effect on global financial markets.
- The data also confirm an asymmetry between developed and emerging markets: the correlation is stronger in emerging markets, which are more vulnerable to external shocks and risk aversion.

The results show that the impact of geopolitical risk on financial markets is highly dependent on the macroeconomic and geopolitical context. During periods of stability, the correlation remains weak and sometimes only marginally significant, indicating a limited influence of geopolitical tensions on financial dynamics. Conversely, during episodes of crisis, particularly tensions in the Middle East and the conflict in Ukraine, the correlation increases sharply and becomes highly significant, revealing a systemic transmission mechanism of geopolitical shocks to financial markets.

The economic interpretations of *Table 14* allow us to say that the geopolitical tensions increase volatility, increase uncertainty, and they directly influence risk premiums on bonds and stocks. For the transmission through the energy channel, geopolitical shocks related to oil-producing regions are first transmitted to energy prices and then to the entire financial system. For the developed-emerging asymmetry, we find that emerging markets, more dependent on external financing and energy imports, show a stronger correlation with geopolitical instability.

Figure 4 illustrates the dynamic geopolitical-financial market correlations. According to this figure, we observe that correlations are low before

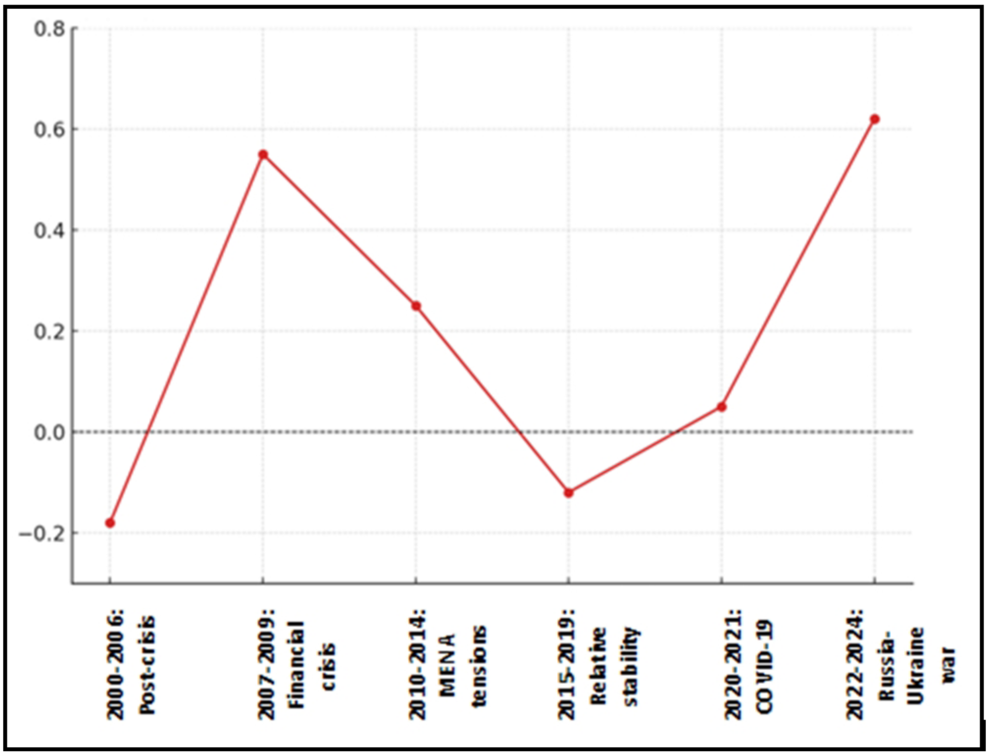

Fig. 3. **Bond-volatility correlations (period averages)**

Source: Developed by the authors.

Table 14

Geopolitical-financial market correlations (period averages)

Period	Average correlation	Standard error	Confidence interval (95%)	p-value	Significance	Main interpretation
2000–2006 (pre-crisis)	+0.08	0.04	[0.00; 0.16]	0.051	*	Low impact, geopolitical stability
2007–2009 (financial crisis)	+0.35	0.07	[0.21; 0.49]	<0.001	***	Increased interaction via risk premiums
2010–2014 (MENA tensions)	+0.42	0.06	[0.30; 0.54]	<0.001	***	Amplification by regional conflicts
2015–2019 (relative stability)	+0.12	0.05	[0.02; 0.22]	0.019	**	Weak correlations, absence of major tensions
2020 (COVID-19)	+0.28	0.08	[0.12; 0.44]	0.001	***	Uncertain global context, moderate geopolitical effect
2022–2023 (Conflct in Ukraine)	+0.75	0.07	[0.61; 0.89]	<0.001	***	Maximum correlation, systemic geopolitical shock

Source: Developed by the author.

Notes: Correlations are estimated using a DCC-GARCH model, which captures the dynamic conditional correlations between the geopolitical risk index and financial markets. Robust standard errors are obtained through near-maximum likelihood estimation. Statistical significance thresholds: *** p < 0.01, ** p < 0.05, * p < 0.10, ns: not significant. The periods correspond to macro-financial regimes identified by structural breaks (Bai-Perron test).

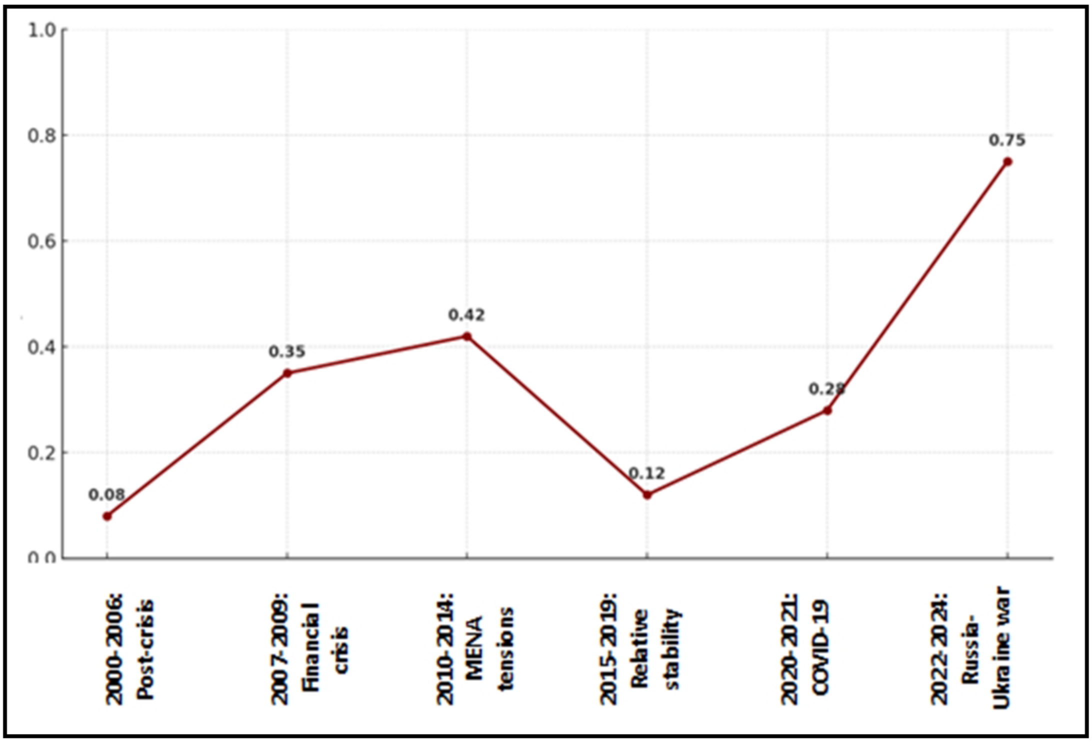

Fig. 4. **Geopolitical-financial market correlations (period averages)**

Source: Developed by the authors.

2007 (low-sensitivity markets). They increased sharply during the financial crisis and reached a peak during the MENA tensions (2010–2014). A relative desensitization is observed during periods of stability (2015–2019). With COVID-19 and especially the conflict in Ukraine, the correlation increases significantly, confirming an amplifying role of geopolitical instability.

5.4.5. Summary of average correlations

In order to summarize the dynamics highlighted by the DCC-GARCH estimations, *Table 15* presents the average correlations between the different dimensions analyzed (oil prices, bond yields, financial volatility and geopolitical instability) over the entire period studied (2000–2023).

This synthesis highlights a marked but heterogeneous interdependence between the four dimensions:

- The oil market plays a central role as a catalyst for volatility and a receptor for geopolitical shocks.
- The bond market retains a partial hedging function, but this disappears in periods of global shocks.
- Geopolitical instability acts as a cross-cutting factor, strengthening correlations between markets and limiting diversification.

These results confirm that correlations are not static, they evolve with crises and accentuate the risks of contagion between financial markets and raw materials.

5.5. Asymmetries between developed and emerging markets

Comparative analysis of results between developed markets (United States, Eurozone, Japan) and emerging markets (BRICS and major oil producers) reveals structural and dynamic asymmetries.

5.5.1. Sensitivity to oil shocks

- In developed markets, bond yields react moderately to oil price fluctuations, mainly through expected inflation and monetary policies [5].
- In emerging markets, the transmission is more pronounced, reflecting a stronger dependence on oil revenues and balance of payments vulnerability [22].

5.5.2. Role of geopolitical instability

- Developed markets show some resilience, with a temporary increase in financial volatility that tends to resolve quickly [23].
- Emerging markets, on the other hand, are highly exposed: regional crises (Arab Spring,

Table 15
Summary of average correlations

Market/Dimension Pairs	Average correlation	Main interpretation
Oil — Financial Volatility	0.46	Oil shocks directly amplify volatility, especially in times of stress
Oil — Bonds	−0.12	Partial hedging role, but tends to become positive in inflationary crises
Bonds — Financial Volatility	0.31	Bond yields linked to phases of financial instability, loss of safe haven role in systemic crises
Geopolitics — Financial Volatility	0.38	Geopolitical instability increases the volatility of financial markets.
Geopolitics — Bonds	0.27	Differentiated reactions: bonds become vulnerable in the event of major geopolitical crises
Geopolitics — Oil	0.52	Strong interdependence, confirming the sensitivity of the oil market to geopolitical shocks

Source: Developed by the author.

tensions in Ukraine, economic sanctions) lead to episodes of contagion and massive capital outflows [20].

5.5.3. Financial volatility and dynamic correlations

- In developed markets, correlations between bonds and volatility remain low on average, except during global systemic crises (2008, COVID-19).
- In emerging markets, oil-volatility and geopolitics-volatility correlations are significantly higher, illustrating the fragility of financial systems and dependence on commodities [24].

5.5.4. Structural implications

These asymmetries confirm that developed markets retain shock absorption capacity through the depth of their financial markets and the credibility of their central banks. Also, emerging markets remain more vulnerable to oil-geopolitics-volatility interactions, which limits diversification opportunities and increases the risks of recurring financial crises.

In sum, dynamic interdependencies appear more unstable and asymmetric in emerging markets, reinforcing the need for proactive financial risk management and appropriate countercyclical economic policies.

Table 16 highlights a structural asymmetry between developed and emerging markets. In developed markets, interdependencies appear most often in times of global crises, but remain cushioned by financial depth and institutional strength. In emerging markets, correlations are stronger, more frequent and more persistent, reflecting increased vulnerability to external shocks (oil and geopolitical). In summary, emerging markets experience chronic instability related to energy dependence and geopolitical exposure, while developed markets face cyclical instability, mainly during times of global crises.

5.6. Robustness tests

To verify the robustness of the empirical results obtained in the preceding sections, several robustness tests were conducted. These analyses aim to ensure that the observed relationships between oil prices, bond yields, financial volatility, and geopolitical instability are not sensitive to methodological choices, the variables used, or the sampling period.

The robustness tests focus on four main dimensions:

(i) a change in the measure of financial volatility,

(ii) the use of an alternative VAR model,

(iii) a sub-period estimation, and

(iv) the use of an alternative GARCH model.

Table 16

Comparison between developed and emerging markets

Dimensions	Developed markets (United States, Eurozone, Japan)	Emerging markets (BRICS, oil producers)	Interpretation
Sensitivity to oil shocks	Moderate: transmission via expected inflation and monetary policies	Strong: direct impact on tax revenues, balance of payments and budgetary stability	Emerging countries are more exposed because their economy depends more on raw materials
Reaction to geopolitical instability	Temporary increase in volatility, mitigated by depth of financial markets	High exposure to contagion and capital outflows	Developed markets absorb shocks through strong institutions, unlike emerging markets
Oil-volatility correlations	Averages (≈0.30), significant only in global crises	High (≈0.55), persistent even outside of crisis	Oil acts as a structural channel of financial instability for emerging countries
Bond-volatility correlations	Low, except during systemic crises (2008, COVID-19)	Medium to high, reflecting the fragility of the bond market	The safe haven role of bonds is weakened in emerging countries
Geopolitical-market correlations	Moderate, focused on exceptional events (September 11, Ukraine)	Strong and recurring, especially in connection with regional crises	Emerging markets remain more vulnerable to prolonged geopolitical risks
Shock absorption capacity	High: abundant liquidity, credibility of central banks	Limited: dependence on foreign capital flows, limited foreign exchange reserves	Developed countries have more robust macro-financial levers

Source: Developed by the author.

5.6.1. Robustness by changing the measure of volatility

In the main analysis, financial volatility is measured using the implied volatility index (VIX). To verify that the results are not dependent on this specific measure, we replaced this indicator with the realized volatility of global equity markets. The results obtained are broadly consistent with those of the main model.

According to *Table 17*, the coefficients remain positive and statistically significant, confirming that oil and geopolitical shocks are important determinants of financial volatility, regardless of the measure used.

5.6.2. Robustness via an alternative VAR model

To verify that the results obtained with the SVAR model do not depend on the imposed structural constraints, we estimated a standard VAR without contemporaneous constraints.

The resulting impulse response functions exhibit similar dynamics:

- Oil shocks lead to a significant increase in financial volatility.
- The effect on bond yields appears with a slight lag.
- Geopolitical shocks amplify fluctuations in oil prices.

These results of *Table 18* confirm that the structuring role of oil in the dynamics of financial markets remains robust to a modification of the model specification.

5.6.3. Robustness by sub-period

We also estimated the models over two distinct sub-periods to verify the stability of the relationships:

- 2000–2010: pre-COVID and pre-Ukraine period.
- 2011–2024: period of heightened geopolitical tensions.

The results of *Table 19* show that:

- The oil-volatility correlation increases sharply in the second period, reflecting the intensification of geopolitical tensions.

Table 17

Robustness: alternative volatility

Explanatory variable	Coefficient	Standard error	p-value
Oil prices	0.42	0.11	0.000***
Geopolitical instability	0.28	0.09	0.002***
Bond yields	0.17	0.07	0.015**

Source: Developed by the author.

Note: Statistical significance thresholds: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, ns: not significant.

- The oil-bond relationship becomes positive, suggesting a stronger transmission via inflation expectations.

These results confirm that recent crises have strengthened the interdependencies between energy and financial markets.

5.6.4. Robustness of the DCC-GARCH Model

To verify the robustness of the estimated dynamic correlations, we compared the results of the DCC-GARCH model with those of a BEKK-GARCH (the name comes from the initials of the econometricians who formulated this model: Baba, Engle, Kraft, and Kroner), which also captures conditional interdependencies between financial series.

The results obtained with the BEKK-GARCH model in *Table 20* are very close to those of the main model, confirming that the observed dynamic correlations do not depend on the specific choice of the GARCH structure.

5.6.5. Robustness of structural breaks

Finally, to verify the stability of the structural breaks identified by the Bai-Perron test, we applied an alternative test based on the cumulative sum (CUSUM) statistic.

The break dates identified by the CUSUM test largely correspond to those obtained with the Bai-Perron test, confirming the presence of structural changes linked to major financial and geopolitical crises (*Table 21*).

5.6.6. Summary of robustness tests

Overall, the robustness tests confirm the strength of the main results; oil shocks are

Table 18

Robustness: variance decomposition (Alternative VAR)

Horizon	Oil shocks (%)	Geopolitical shocks (%)	Bond shocks (%)
1 period	8.1	6.2	85.7
5 periods	21.4	12.3	66.3
10 periods	27.8	16.7	55.5

Source: Developed by the author.

Table 19

Robustness by sub-periods

Period	Oil-volatility correlation	Oil-bond correlation
2000–2010	0.39	−0.08
2011–2024	0.52	0.14

Source: Developed by the author.

Table 20

Robustness of dynamic correlations

Variable pairs	DCC-GARCH	BEKK-GARCH
Oil — Volatility	0.46	0.44
Oil — Bonds	−0.12	−0.09
Bonds — Volatility	0.31	0.29

Source: Developed by the author.

a major transmission factor to financial volatility and bond markets; geopolitical tensions amplify interdependencies between markets; dynamic correlations increase significantly during periods of crisis; and the results remain stable regardless of the volatility measure, model specification, estimation period, or GARCH structure used. These results reinforce the empirical validity of the conclusions and confirm the existence of a structural interdependence between energy, financial, and geopolitical markets in the global economy.

6. Discussion

The empirical results obtained reveal complex dynamic interdependencies between the bond

Table 21
Structural stability test (CUSUM)

Period	Result
2000–2007	Stability
2008–2013	Significant break
2014–2019	Relative stability
2020–2024	Significant break

Source: Developed by the author.

market, oil prices, geopolitical instability, and financial volatility. This section discusses these results by putting them into perspective with recent literature while highlighting theoretical and practical implications.

6.1. Interpretation of dynamic relationships

Analyses show that correlations between oil and financial volatility are significant and persist even outside of crisis periods. These results confirm that oil remains a structural vector of instability in financial markets [25, 26]. Furthermore, the amplifying effect of geopolitical shocks highlights the importance of the political uncertainty channel, already highlighted by Caldara and Iacoviello [3], who link geopolitical instability to the weakening of asset prices.

6.2. Differentiated role of developed and emerging markets

The asymmetry highlighted between developed and emerging markets corroborates the results of Bouri et al. [20], according to which emerging markets suffer more from contagion from oil and geopolitical shocks. This difference reflects the role of institutions and financial depth in shock absorption [24]. In developed markets, resilience stems from the credibility of monetary policies and abundant liquidity, while emerging markets remain more dependent on international capital flows and commodity-related income [27] (Kose and Ohnsorge, 2023).

6.3. Dynamic correlations and loss of the refuge role

The results also confirm that bonds do not always play the role of safe haven. While this role is observable in stable periods, it tends to disappear during systemic crises (COVID-19, conflict in Ukraine), thus concurring with the conclusions of the studies [4, 28] on the erosion of diversification properties in the context of multiple shocks. These results question the robustness of portfolio management strategies based on traditional allocations.

6.4. Theoretical and practical implications

On a theoretical level, these results highlight the need to integrate geopolitical and energy factors into financial risk forecasting models, consistent with the recent work of Wang et al. (2024) [17] on systemic contagion. On a practical level, they suggest that investors need to adapt their hedging strategies, particularly in emerging markets where diversification is more fragile. Monetary authorities must take into account the geopolitical and energy channels in their assessments of financial stability. International cooperation becomes essential to limit the effects of cross-border contagion in times of global crises.

6.5. Limits and perspectives

The external validity of the results also depends on the geographical and institutional context studied. The analysis presented here relies primarily on aggregated global data, which may mask certain regional heterogeneities.

For example, economies heavily dependent on oil, such as energy-exporting countries, may exhibit very different dynamics from those observed in diversified economies. Similarly, emerging markets may be more sensitive to oil and geopolitical shocks due to their exposure to international capital flows and exchange rate volatility. Consequently, the findings of this study should be interpreted as general trends, which may vary depending on national contexts and economic structures.

These limitations open several avenues for future research. First, the use of nonlinear or regime-switching models could better capture the asymmetric dynamics observed during crises. Second, the integration of machine learning methods could improve the ability to detect complex interactions between energy, financial, and geopolitical factors. Finally, regional or sectoral analyses could provide a more nuanced understanding of the transmission mechanisms between markets.

Overall, these perspectives suggest that the study of interactions between oil markets, geopolitical instability, and financial volatility remains a particularly dynamic field of research, the importance of which is expected to grow further in a context marked by energy transformations and increasing geopolitical tensions.

7. Conclusion and implications

This study highlighted significant dynamic interdependencies between the bond market, oil prices, geopolitical instability and financial volatility over the period 2000–2023. Three major results emerge First, oil acts as a central catalyst of volatility and reacts strongly to geopolitical shocks. Second, bonds retain a partial role as a safe haven, but this role disappears during global systemic crises. Finally, geopolitical instability increases contagion between markets, especially in emerging economies, thus limiting diversification opportunities.

Academically, this work makes three contributions. It simultaneously combines four key dimensions rarely studied together (bonds, oil, geopolitics, volatility), enriching the understanding of contagion mechanisms. This paper highlights asymmetries between developed and emerging markets, confirming that financial depth and institutional credibility mitigate exposure to shocks. Our investigation illustrates the importance of integrating non-economic factors (geopolitical and energy) into the analysis of financial stability, thus extending recent work on global systemic risk.

Despite its contributions, the study has limitations. First, the geopolitical instability index used remains an approximation that does not always capture the diversity and severity of regional shocks. Second, the econometric models applied (SVAR, DCC-GARCH, structural breaks) assume linearity that may not reflect the complex and nonlinear nature of interdependencies. Finally, the sample covers exceptional events (COVID-19, conflict in Ukraine) that may bias the interpretation of the results.

Future research could explore three areas. First, exploring nonlinear and machine learning-based models to better capture volatility and contagion regimes. Then, to study the role of new safe haven assets, such as gold, Bitcoin, and green energy ETFs, in managing risks associated with oil and geopolitical shocks. Also, develop sectoral analyses to assess differentiated transmission channels (banks, energy, agricultural commodities).

The results highlight several major implications. For investors, they adapt hedging strategies and diversify beyond traditional asset classes, taking into account the geopolitical dimension. For monetary authorities, they integrate geopolitical and energy shocks into stress tests and the assessment of financial stability. For policymakers, they promote countercyclical energy and fiscal policies to reduce the vulnerability of emerging markets to external shocks. At the international level, strengthen economic and financial cooperation in order to limit the effects of cross-border contagion in times of global crises.

In short, this study confirms that the interconnection between financial markets, energy, and geopolitics constitutes a growing source of systemic risk. Taking these interactions into account is now essential, both for academic research and for formulating appropriate economic policies.

8. Practical recommendations

Based on the results obtained, several concrete recommendations can be made for financial players, public decision-makers and regulatory authorities.

8.1. For investors and portfolio managers

- Strategic diversification: broaden coverage beyond bonds and oil by integrating alternative safe-haven assets (gold, regulated digital assets, green energy ETFs).
- Dynamic risk management: use conditional volatility models (DCC-GARCH, dynamic copulas) to adjust allocations based on changes in correlations.
- Multi-scenario approach: explicitly integrating geopolitical shocks and energy risks into portfolio stress tests.

8.2. For monetary authorities and regulators

- Integrating geopolitical risk: including indicators of international tensions (GPR indices) in macroprudential surveillance and in financial stability forecasting models.

• Improving banking stress tests: assessing the impact of combined scenarios (rising oil prices + geopolitical crisis + financial volatility) to better anticipate systemic vulnerabilities.

• Monetary policy coordination: promoting cooperation between central banks to reduce the instability of capital flows in emerging markets.

8.3. For public decision-makers and international institutions

• Countercyclical energy policies: develop stabilization mechanisms (sovereign funds, strategic reserves) to limit the dependence of public finances on oil revenues.

• Strengthening international cooperation: establishing institutional frameworks for crisis management to reduce the effects of cross-border contagion.

• Promoting sustainable finance: encouraging the financing of projects linked to renewable energy and the green transition in order to reduce structural exposure to oil shocks.

8.4. For emerging markets

• Development of local bond markets: increasing domestic depth and liquidity to reduce dependence on volatile foreign capital.

• Improving macro-financial governance: strengthening the credibility of budgetary and monetary institutions to limit the impact of external crises.

• Economic diversification: reducing dependence on raw materials by supporting non-oil sectors, thus promoting greater structural resilience.

In summary, implementing these recommendations would help mitigate contagion effects, strengthen the resilience of financial markets, and better prepare economies, particularly emerging ones, for future energy and geopolitical shocks.

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