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Volatility Spillover Between Financial And Commodity Markets: A Theoretical Synthesis Of Transmission Mechanisms, Measurement Approaches, And Policy Implications

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Abstract
This paper synthesises the theoretical literature on volatility spillover between financial and commodity markets in order to create a framework for the research on this subject, which has grown significantly since the global financial crisis of 2008 led to greater financialization of commodities. Volatility spillover encompasses the spread of volatility risk across markets, via channels such as investor behaviour, common macroeconomic shocks, and index funds and exchange-traded products (ETPs) that trade across markets. The review brings together three strands of literature: theoretical channels of communication (financialization, information transmission, behavioural contagion), the development of measurement methodology from the early multivariate GARCH frameworks to the Diebold–Yilmaz connectedness index and its time-varying parameter vector autoregressive (TVP-VAR) extension, and applied evidence from energy, precious metals, agriculture and cryptocurrency markets, with a particular emphasis on crisis periods such as COVID-19 and the Russia–Ukraine conflict. The synthesis suggests that the financial and commodity market connectedness is regime-dependent and ramps up markedly when systemic stress occurs, and that transactions between markets can flow from the financial to commodity markets or from the commodity to the financial markets, depending on the commodity sector and the nature of the shock. The paper ends with a discussion on gaps in methodology and policy implications in the context of diversifying portfolios, systemic risk regulation and the growing challenge for macroprudential policy to monitor and influence increasingly interconnected global markets.

Keywords: volatility spillover; connectedness; commodity markets; financialization; TVP-VAR; Diebold–Yilmaz; systemic risk.

1. Introduction

Volatility spillover is the spread of price risk or uncertainty from one market to another, which is sometimes referred to interchangeably as the concept of connectedness (Diebold & Yilmaz, 2012, 2014) [9][10]. While price correlation is a measure of co-movement in prices at the same time, spillover analysis focuses on the directionality of the shock transmission, and delineates between markets that are mostly volatility transmitters and those that are mostly volatility receivers. For portfolio managers looking for diversification benefits, for regulators who worry about systemic risk, and for policy makers in commodity reliant economies who are at risk from imported financial instability, this difference is very important.

This paper is a theoretical and review one. It does not provide new empirical estimates, but puts together the conceptual basis, the development of econometric methods, and the substantive results of the volatility spillover literature that has been published mainly since 2015 and continues through the financialization debate of the early 2010s and into the COVID-19 crisis, the Russia–Ukraine conflict of 2022, and the subsequent expansion of cryptocurrency markets as another link in the world's spillover chain. The goal is to develop a theoretical structure that ties together the channels of volatility transmission, the methods of measure, and the empirical facts about the interaction between financial and commodity market volatility.

The rest of the paper is organized as follows. In this section, the general theoretical pathways leading to volatility spillover are revisited. Section 3 discusses the developments of econometric tools for assessing spillover and connectedness. Section 4 draws together empirical evidence on the key commodity classes and crisis periods. Theoretical and policy implications are discussed in Section 5. Section 6 points to limitations and future research, and Section 7 concludes.

2. Theory of Volatility Transmission Channels

Several, apparently overlapping, theoretical channels have been identified in the literature for transmitting volatility between financial and commodity markets.

2.1 The Financialization Channel

The financialization hypothesis suggests that the rise of commodity index funds and exchange-traded funds (ETFs) in the capital markets has changed the way commodity prices are set, so that they are now influenced by the sentiment in the broader financial markets as well as by commodity fundamentals (Antonakakis & Kizys, 2015) [2]. Under this channel, commodity prices start to co-move more with equities and other risk assets as commodities are part of common multi-asset portfolios, and the shock to investor risk appetite or liquidity conditions in financial markets is mechanically passed through to commodity prices when investors rebalance their portfolios at the same time. The theory of this channel is that volatility spreading from equities to commodities is expected to have increased after the mid-2000s growth in commodity index investment and should be largest for commodities that have a high percentage of their investments in commodity indices, as is the case for crude oil and gold.

2.2 The Information Transmission Channel

Another channel is the progressive or sudden transmission of macroeconomic and market-specific information from market to market. Financial markets, especially equities and currency markets, tend to respond to new macroeconomic news and price it more rapidly than physical commodity markets, and hence, a shock like a change in monetary policy expectations, in the currency valuation or in global risk sentiment is often felt first in the price of financial assets and then in the price of physical commodities. This channel is consistent with the price discovery literature and suggests a lead–lag relationship where financial markets serve as an early warning system to the subsequent volatility in commodity prices, especially those priced in and/or sensitive to the US dollar, like crude oil and gold.

2.3 The Common Shock and Macro-Financial Channel

However, the co-movement of volatilities does not necessarily mean that there is a direct causal transmission mechanism but may rather be a simultaneous reaction to a common "shock," such as a global pandemic, a geopolitical conflict, a monetary policy surprise or an energy supply disruption (Zhang, Hu, & Ji, 2020) [22]. The recent COVID-19 pandemic and the 2022 Russia–Ukraine conflict have been often mentioned in the literature as examples of common shocks that had a simultaneous increase in volatility across equity, energy, precious metal and agricultural markets (Banerjee, Sensoy, & Goodell, 2024) [4], and, from a statistical standpoint, these shocks represent the case of shared exposure to systemic macro-financial risk. A key methodological difficulty in the literature is to differentiate between the effects of cross-market transmission from common shocks.

2.4 The Behavioural and Liquidity Contagion Channel

A second channel highlights the importance of investor behaviour in a stressed environment, such as herd behaviour, safety-seeking and liquidity contagion. Commodity volatility transmission that is unrelated to commodity fundamentals occurs when during a time of financial turmoil, investors under pressure to meet margin calls or to sell stocks that are in short supply may be forced to sell unrelated commodities. This channel offers a rationale for the often-times asymmetric and regime-dependent intensity of spillovers, which tend to escalate in the midst of a crisis and fade during periods of peace, as described in the literature as "time varying" or "regime switching" connectedness.

2.5 The Energy-Centrality Channel

In the commodity complex itself, as well as in energy markets, especially in crude oil, they are often singled out as a key transmission node (Xiang et al. 2024) [20]. Crude oil volatility has been reported to impact other commodity markets as well as financial markets as a direct consequence of its effect on energy prices, which, as an input in the production of other commodities, like agricultural products through the increased fertilizer prices, also has direct macroeconomic implications for inflation and growth, further cementing its role as a major node in the global spillover network.

3. Development of Measurement Methodology

The process of empirical measurement of volatility spillover has changed significantly, and knowledge of this process is crucial to the interpretation of the theoretical and applied literature reviewed and consolidated in this paper.

3.1 Early Multivariate GARCH Approaches.

The first generation of spillover analysis was based on multivariate generalized autoregressive conditional heteroskedasticity (GARCH) models such as the BEKK-GARCH, VAR-GARCH and dynamic conditional correlation (DCC-GARCH) models. The models can incorporate the possibility that conditional variances and covariances between two or more asset returns can change over time and have been extensively used for pairs or small systems of financial and commodity assets, e.g., crude oil and stock market indices, or gold and currency markets. Multivariate GARCH models are hard to estimate when the number of markets increases, and therefore are not used in large connectedness networks.

3.2 Yilmaz–Diebold Connectedness Framework.

It was the introduction of the spillover index, defined as the generalized forecast error variance decomposition of a vector autoregression model, or the Diebold–Yilmaz framework (Diebold & Yilmaz, 2012, 2014), [9], [10] which was a methodological breakthrough. This approach creates an overall connectedness index that represents the average proportion of forecast error variance in each market associated with shocks from the other markets in the system, and additionally breaks this measure down into market-specific net, pairwise, and directional spillover indices to uncover which markets at a given time serve as net transmitters of volatility and which net receivers. It is the scalability to large systems of markets and the ability to generate an intuitive and normalized measure of overall system connectedness that is the main new aspect of this framework when compared to multivariate GARCH models.

3.3 The Time-Varying Parameter VAR Extension

Subsequent developments of the Diebold–Yilmaz method (Antonakakis, Chatziantoniou, & Gabauer, 2020) [1] introduced a time varying parameter vector autoregressive model to replace the rolling window VAR, eliminating the need to specify a rolling window, which causes loss of observations. The resulting TVP-VAR connectedness framework has been the main method in recent papers on financial-commodity spillover as it better reflects the empirical phenomenon of volatility clustering in both financial and commodity market, as well as the fact that it is able to better capture the sharp spikes of connectedness around crisis events than fixed or rolling-window estimates (Chatziantoniou & Gabauer, 2021) [7].

3.4 Frequency-Domain and Quantile Extensions

Recent methodological work has further developed the concept of connectedness in two further dimensions. First, frequency domain decomposition techniques enable the identification of spillover effects as transitory (shock-driven) and persistent (structurally embedded) connectedness between markets (Baruník & Křehlík, 2018) [5]. Second, quantile connectedness methods rely on the entire distribution of returns, not just the conditional mean or variance, and capture tail-risk spillovers that occur in the tail especially in times of extreme market downturn (Chatziantoniou, Gabauer, & Perez de Gracia, 2022) [8]. The two extensions are part of a larger movement in the literature that takes into account the asymmetric and/or idiosyncratic nature of cross-market volatility transmission rather than assuming a single, time-invariant transmission intensity.
This course covers Network and Machine Learning Approaches.

More recent methodological advances signal connectedness as directed network graphs, and make use of network methods to identify systemically relevant nodes, transmission hubs and contagion channels in the financial-commodity network. At the same time, recent papers have started integrating deep learning architectures, such as long short term memory networks, to identify true volatility signal from the noise in connectedness estimation problems, and to develop early-warning indicators that predict volatility increases related to systemic crises before they happen in traditional spillover indices (Şahiner, 2023) [19].

Table 1 presents the main methods employed by the literature reviewed in this paper, ranging from the initial multivariate GARCH models to recent network and machine-learning indices of connectedness.

Table 1. Evolution of volatility spillover measurement methodology

Approach	Core Idea	Strength	Limitation
Multivariate GARCH (BEKK, DCC)	Models time-varying conditional variance/covariance between asset pairs	Captures volatility clustering directly; well established	Poor scalability beyond small systems
Diebold–Yilmaz Spillover Index	Forecast error variance decomposition from a VAR	Intuitive total/directional/net spillover measures; scalable	Rolling-window choice is arbitrary; loses observations
TVP-VAR Connectedness	Kalman-filtered time-varying VAR parameters	Captures abrupt regime shifts without window loss	Computationally intensive; sensitive to lag selection
Frequency-Domain (Barunik–Krehlik)	Decomposes spillover into short- and long-run components	Distinguishes transitory from persistent connectedness	Requires additional parameter choices for frequency bands
Quantile Connectedness	Extends VAR connectedness across the return distribution	Captures asymmetric tail-risk spillovers	Interpretation more complex; data-intensive
Network/Machine Learning	Graph-based and deep-learning representation of connectedness	Identifies systemic hubs; early-warning potential	Less theoretically transparent; emerging methodology

4. Creation of Empirical Evidence

4.1 Energy Markets and Equities

Crude oil is always found in the literature as one of the most systemic connected commodities, where volatility spillovers run both ways from the equity markets, and they become more pronounced in times of crisis. Indeed, findings from the COVID-19 pandemic period show that the volatility transmission between the U.S., China and India crude oil markets and stock markets has been higher than that during the 2008 global financial crisis, suggesting that the pandemic-related shock in demand has occurred simultaneously in both types of markets in an unprecedented manner (Han, Liu, & Chen, 2024; [11] Mao, Wang, & Chen, 2024 [15]). Geopolitical risk also is found to be a significant push factor for oil price volatility, with spillover effect running primarily from oil to equity markets, which is in line with the resource-dependence and macroeconomic channels outlined in Section 2 (Caldara & Iacoviello, 2018; Salem et al., 2025)[6].

4.2 Precious Metals

Due to their traditional role as safe-haven assets, gold and other precious metals have a singular place in the spillover network (Mensi, Ali, Vinh, & Kang, 2022) [16]. Empirical studies on the COVID-19 and Russia–Ukraine episodes have found that structurally, gold is connected to the rest of the connectedness network, but at the same time it has been found that it is a net receiver of volatility shocks during periods of acute financial stress, consistent with its safe-haven function (Hoque, Sahabuddin, & Bilgili, 2024) [12]. The duality is both of a hedge and of a financial integrated asset: both can be used to remove volatility from the price series while in one market regime, and to add it in another.

4.3 Agricultural Commodities

Net receivers rather than net transmitters of volatility within the commodity complex are more commonly identified in the literature as agricultural and livestock commodities, while energy, industrial metal and precious metal markets are the main sources of information transmission (Xiang et al., 2024) [20]. This is similar to the energy-centrality channel mentioned above because the cost of agricultural production is related to the price of energy and fertilizer. Concurrently, the net volatility spillover of agriculture and livestock markets was found to be positively affected by geopolitical risk, particularly relevant in the current context since wheat, maize and other staples play a prominent role in food security during times of food supply disruptions like the Russia–Ukraine war where the two countries share significant market shares of wheat exports (Zhang, Wang, & Liu, 2024) [23].

4.4.1 Cryptocurrency Markets as an Emerging Node

The development of cryptocurrency markets, and specifically the bitcoin market, has added another node to the financial-commodity connectedness network. Evidence in the middle of the 2020s suggests that volatility of cryptocurrencies, major equity indexes, and commodities like gold and crude oil are becoming more intertwined, especially in the jump components of realized volatility, during periods of greater market stress (Jena, Tiwari, Hammoudeh, & Roubaud, 2023; [13] Liu, Julaiti, & Gou, 2024[14]). Tighter linkages between digital assets and traditional financial or commodity markets, as shown by more recent evidence since the institutionalisation of cryptocurrency markets through the introduction of regulated exchange-traded products, imply that cryptocurrencies are increasingly becoming less segregated from traditional markets, which may affect their performance as a diversification asset (Structural Spillovers, 2026; Yaya, Vo, & Akinsomi, 2022) [21].

Using the crisis episode as a natural experiment.
In all of the literature examined, the crisis episodes serve as natural experiments, with each giving similar results on the regime-dependent nature of volatility connectedness. Regardless of the markets studied, the total connectedness indices rise significantly during the global financial crisis in 2008, the oil price drop between 2014 and 2016, the COVID-19 pandemic, and the Russia–Ukraine conflict, and then slowly normalize after the shock has passed (Zhang, Hu, & Ji, 2020) [22]. Spillover effects are also observed to be stronger for certain shock types than others, with shocks related to health sometimes leading to greater overall spillover effects than geopolitical shocks, and commodity markets and energy in particular identified as the main conduit of shocks during the geopolitical shock specifically (Hoque, Sahabuddin, & Bilgili, 2024) [12].

Table 2. Synthesis of typical transmitter/receiver roles by commodity class.

Commodity Class	Typical Role	Key Driving Shock(s)	Representative Finding
Crude Oil / Energy	Net transmitter	Geopolitical risk, supply disruption, COVID-19	Oil-to-equity spillover intensified beyond 2008 GFC levels during COVID-19
Precious Metals (Gold)	Net receiver in crises; safe haven	Flight-to-safety, financial stress	Gold acts as safe haven during COVID-19 and Russia–Ukraine war
Agricultural / Livestock	Net receiver	Energy costs, geopolitical risk, war	Energy and industrial metals transmit to agriculture and livestock

Industrial Metals	Net transmitter	Global growth expectations, geopolitical risk	Acts as information transmitter alongside energy and precious metals
Cryptocurrencies	Growing bidirectional node	Institutionalization, ETF approval, monetary tightening	Structural strengthening of crypto-equity-gold linkages post-2024

5. The implications of the findings are presented and discussed from a theoretical and policy perspective.

5.1 The Dividend Discount Model.

The increase in the connectedness of equities and commodities due to the financialization process has direct implications for portfolio theory. Although commodities are conventionally thought to be a diversifier with low or negative correlation to stocks, the results of this paper align with the broader literature on the tendency for correlation breakdown during crises that suggests that this diversification effect may not persist in all circumstances, and may actually vanish at the very time it is most needed, when markets are stressed (Sayed & Charteris, 2022) [18]. But even gold is not immune from the wider network of connectedness, as it continues to possess safe-haven qualities.

5.2 The impact of Systemic Risk Regulation. Impact of Systemic Risk Regulation

At a macroprudential level, the fact that energy markets and crude oil, in particular, appear to be a recurring central node in the spillover network implies that regulators that are interested in systemic risk should keep an eye on energy market volatility not only because of the direct economic impact of volatility in the energy market but also because of the potential to transmit instability to equity and other commodity markets. While static, unconditional risk measures provide macroprudential regulators with less granular tools for identifying markets as systemic transmission hubs at any given time, network-based and machine-learning methodologies discussed in Section 3.5 may provide increasingly granular tools (Chatziantoniou & Gabauer, 2021) [7].

5.3 The role of trade in development.

The findings that geopolitical risk and global financial shocks have direct links to the volatility of agricultural and energy markets have important implications for food security and fiscal policies for economies highly exposed to commodity trade. In commodity-dependent economies, policies that limit exposure to imported volatility, such as strategic reserves, diversified trading partners, and in the context of other papers in this series, building domestic futures and warehousing markets that enable producers to hedge against price volatility from the global markets instead of from local markets, may benefit the governments.

5.4 Digital assets implications for treatment

As cryptocurrency markets become part of the larger network of connectedness between the financial and commodity sectors, these have implications for how the markets are regulated and how investors participate in them. Historically, digital assets have been favoured as an uncorrelated diversification asset, whereas with the growing institutionalization through regulated investment vehicles, the appeal for diversification diminishes and the potential for extra channel of contagion in times of systemic stress rises, both for portfolio risk management and for the overall regulatory treatment of digital assets in the financial system (Liu, Julaiti, & Gou, 2024) [14].

6. Restrictions and future recommendations

The literature reviewed has some limitations and points to areas of future studies.

However, there is a methodological difficulty in separating genuine cross-market transmission from the co-movement of volatility due to simultaneous exposure to common macro-financial shocks, and much of the literature documents co-movement in volatility without addressing this issue. Although the structural channel of transmission has been proposed in recent literature, it remains methodologically challenging due to the difficulty of disentangling the common shocks from the genuine cross-market transmission.

The literature has not yet reached consensus on how to choose the forecast horizon for variance decomposition, and estimates of connectedness are sensitive to the frequency of the data employed (daily, intraday, or lower-frequency data).

Limited integration of structural and reduced-form approaches: the most prevalent connectedness methodologies are reduced-form and, if greater integration with structural macro-finance approaches could be achieved, the economic interpretation of connectedness estimates could be deepened.

Little attention to heterogeneities in regional and emerging markets: Spillover dynamics tend to be discussed more for the large, developed markets or commodities that are traded at an international level, with less attention to the heterogeneities that occur in regional or emerging markets, such as local agricultural spot markets.

Machine learning interpretability: Deep learning and network-based methods are promising for early-warning applications, but the fact that they are less transparent than traditional econometric models is limiting in policy application where interpretable risk measures are needed.

Theoretical models should be developed to explicitly model the micro-foundations of cross-market investor behaviour that accounts for the observed spillover pattern, and the methodology should be further refined for frequency-domain, quantile and machine-learning-based measures of cross-market investor connectedness and applied to the growing number of financialised commodity and digital asset markets.

7. Conclusion

This paper has combined the theoretical channels, methodological development and empirical regularities that link financial and commodity markets in terms of volatility spillover. The reviewed literature reveals that since the mid-2000s, the financialization of commodities has been structurally increasing the linkage between commodity and financial markets, which has taken place through financialization, information transmission, shared macro-financial shocks, behavioural contagion and the role of energy markets in the commodity complex. Methodologically, the field has evolved from a focus on early multivariate GARCH models to the current state-of-the-art TVP-VAR connectedness framework and its extensions in the frequency domain, quantile ranges, and networks, in each case providing a more detailed and flexible view of cross-market transmission. Empirically, connectedness is always found to be regime-dependent and increases during crisis periods such as the global financial crisis, the COVID-19 pandemic, and the Russia–Ukraine conflict, and energy and equity markets are generally identified as net energy transmitters, while agricultural and precious metal markets have more mixed transmitter-receiver characteristics depending on the type of shock. The results have important implications for portfolio diversification, system risk management, and the management of commodity-dependent economies, and suggest a further need for theoretical and methodological development as cryptocurrency and other digital asset markets continue to play an increasing role in the world financial-commodity connectedness network.

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