Unveiling the dynamic linkages and hedging between Indian sectoral indices and alternative investments in crisis episodes

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The international investment trends have shifted the focus from the broad market to specific sectors. The inflow of Foreign Institutional Investors (FIIs) has integrated the Indian market with global markets, leading to increased market volatility, particularly during crises, due to global risk transmission. Therefore, the present study explores the dynamic interconnectedness between major alternative investments, the Indian benchmark index, and its sectoral indices during major crises, such as the global health crisis and the geopolitical conflict. By exploring the hedging and diversification benefits of gold, oil, OVX, and cryptocurrencies in the Indian stock market. By utilizing TVP-VAR, the SPBSX, SPBCD, SPBC, SPBFS, and SPBI consistently transmitter and SPBF, SPBH, SPBIT, and SPBT act as recipients of volatility. Gold is the most effective hedge, whereas oil and CCI.30 are the least effective hedges against the equity sectors. Our research holds significance for investors and managers seeking to enhance risk-adjusted returns through diversification strategies. This is the first study to provide diversification and hedging by exploring the dynamic connectedness between major alternative investments and the Indian sectoral indices during two distinct crises.

JEL Classification: G11, G14, F36, F65

Keywords: Sectoral connectedness, volatility spillover, crisis, gold, oil, cryptocurrency

Revelando los vínculos dinámicos y la cobertura entre los índices sectoriales indios y las inversiones alternativas en episodios de crisis

Las tendencias globales de inversión han reorientado el interés del mercado hacia sectores específicos. La participación de inversores institucionales extranjeros ha integrado al mercado indio con los mercados internacionales, aumentando su volatilidad, especialmente durante crisis, por la transmisión global del riesgo. Este estudio analiza la interconexión dinámica entre inversiones alternativas clave, el índice de referencia indio y sus índices sectoriales durante dos crisis relevantes: la pandemia global y un conflicto geopolítico. Evaluamos el potencial de cobertura y diversificación del oro, petróleo, OVX y criptomonedas frente a los sectores bursátiles indios. Encontramos que los índices SPBSX, SPBCD, SPBC, SPBFS y SPBI actúan como transmisores de volatilidad, mientras que SPBF, SPBH, SPBIT y SPBT son receptores. El oro emerge como la cobertura más efectiva; el petróleo y el CCI.30, como las menos eficaces. Este estudio, pionero en su enfoque, ofrece evidencia valiosa para inversores y gestores que buscan optimizar la rentabilidad ajustada al riesgo mediante estrategias de diversificación sectorial en contextos de crisis.

Clasificación JEL G11, G14, F36, F65

Palabras clave: Conectividad sectorial, repercusión de la volatilidad, crisis, oro, petróleo, criptomonedas

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1. Introduction

Indian stock market is the fourth largest among global equity markets, with a market capitalization crossing $4 trillion. This achievement can be attributed to the significant increase in Foreign Institutional Investments (FIIs) inflows, which was ₹99.33 billion in the fiscal year 2000-01 and reached ₹2748.59 billion by 2023-24, registering a remarkable growth rate of 2,670.32% during the period. In fact, over 60 per cent of the market capitalization is being accounted by FIIs due to the possible opportunities in the market. The inflow of FIIs thus emerged as one of the predominant factors in shaping the dynamics of the Indian market by integrating it with global markets. However, it has also led to heightened market volatility due to the increased probability of global risk transmission, especially in times of crisis. From a theoretical perspective, Modern Portfolio Theory (Markowitz, 1952) posits that combining assets with low or negative correlations can reduce overall portfolio risk. This principle forms the basis for analyzing market connectedness and underscores the potential role of alternative assets as effective hedging or diversification tools. In parallel, the Contagion Theory (Forbes & Rigobon, 2002) explains how financial shocks during crises can propagate across markets, intensifying comovements and risk transmission. Together, these frameworks support the need to examine interactions among asset classes—particularly during periods of stress. As a result, rising volatility in an increasingly integrated global market highlights the importance of exploring robust risk-diversification strategies. Thus, the increased volatility necessitates exploring effective risk-diversification opportunities in integrated market conditions.

Literature on stock market connectedness has proliferated over the last decade, explicitly focusing on crisis periods (Chen, Firth, & Meng Rui, 2002; Vidal-Llana, Uribe, & Guillén, 2023; Yang, Kolari, & Min, 2003; Youssef, Mokni, & Ajmi, 2021). Most of them examined the market connectedness in developed (Aggarwal & Kyaw, 2005; Campbell & Hamao, 1992; Lahrech & Sylwester, 2011; Wang & Xiao, 2023) and developing economies (Égert & Kočenda, 2011; Guo & Ibhagui, 2019; Maiti & Kayal, 2023; Prakash & Nauriyal, 2021; Sahabuddin et al., 2022; Yousaf, Mensi, Vo, & Kang, 2023). Further, some researchers have explored the interconnectedness between gold and stock markets to uncover the diversification opportunities beyond the equity markets (Gulyani et al., 2021; Gürgün & Ünalmiş, 2014), as international gold is a safe haven and a crucial component of many investment portfolios, which tends to exhibit stability or even increase during adverse tail events. It serves as a valuable hedge, potentially shielding investors from unexpected shocks such as crises or extreme market volatility (Cui xiaozhong et al., 2022; Lucey & Li, 2015; W Mensi, Hammoudeh, Al-Jarrah, Sensoy, & Kang, 2017). This hedge is highly valuable, protecting investors against unforeseen shocks like crises or extreme market volatility. Therefore, investors tend to include gold in their investment strategies. In the same vein, some studies have analyzed the relationship between crude oil and equity markets, as crude oil significantly shapes the economy (Awartani & Maghyereh, 2013; Yurteri Kösedağlı, Huyugüzel Kışla, & Çatık, 2021). Few have analyzed the connection between oil, gold, and equity markets (Imran & Ahad, 2023; S H Kang, Tiwari, Albulescu, & Yoon, 2019; Walid Mensi, Yousaf, Vo, & Kang, 2022). Along with this, the financial markets have seen a surge in the popularity of cryptocurrencies, with market capitalization exceeding $1.65 trillion and a wide range of over 1,500 different cryptocurrencies. The growing popularity of cryptocurrency has intensified the research,

and a few have analyzed the connectedness between markets of cryptocurrency and equity (Gupta, Mitra, & Banerjee, 2023; Jana & Sahu, 2023; Le, Abakah, & Tiwari, 2021)

The earlier studies focussed more on market-level connectedness; however, the international investment trends have shifted the focus from the broad market to specific sectors (Sang Hoon Kang, Arreola Hernandez, Rehman, Shahzad, & Yoon, 2023; Vidal-Llana et al., 2023). Despite the extensive research on aggregate market studies, there has been limited exploration of sectoral connectedness in the equity market. Nonetheless, it is crucial to remember that investments focused on specific sectors may remain susceptible to market downturns and the distinct risk (idiosyncratic risk) within each sector. To alleviate these risks, it is imperative to implement strategic diversification that extends beyond particular sectors. Therefore, protection against declines can be obtained by constructing an optimal portfolio of assets that function as hedgers (inversely correlated) and diversifiers (low correlation). This has prompted the exploration of other asset classes, such as gold, oil, and cryptocurrency either as hedgers or diversifiers. Hence, it becomes crucial specifically in times of crisis, where the potential for sector-specific shocks and volatility transmission may be heightened. Investors can effectively diversify their portfolios and mitigate the risk by analyzing this volatility transmission.

Against this backdrop, the present study explores the dynamic interconnectedness between major alternative investments and the Indian benchmark index with its sectoral indices in the recent decade, including the periods of recent crises such as the COVID-19 pandemic (Global health crisis)and the Russia-Ukraine War (Geo political conflict). This study uses gold, oil, OVX (Crude Oil Volatility Index) and cryptocurrency (CCI.30) as alternative investments. Due to the highly volatile nature of oil prices, including implied volatility index such as the OVX is crucial. This index is an important indicator of market sentiment and expectations for future price changes in the oil market. Therefore, it becomes essential to incorporate the OVX in the analysis to investigate the dynamics of the oil market as it captures the investor behaviour and perceptions of risk. Building on this objective, the study hypothesizes that alternative investments such as gold, oil, OVX, and cryptocurrency serve as effective hedging tools or diversification assets against sector-specific risks in the Indian equity market—particularly during crisis periods. Testing this hypothesis through the analysis of dynamic spillovers and net directional linkages will help determine the extent to which these assets can support optimal portfolio strategies in times of elevated uncertainty.

In order to capture the dynamic connectedness between the given components, the study uses the time-varying parameter vector autoregression (TVP-VAR) spillover model. This model captures the dynamic connectedness between these components. This methodology is superior to traditional rolling-window VAR approaches as it: (i) adapts to parameter changes over time, (ii) is robust to outliers, (iii) avoids the need for arbitrary window size selection, and (iv) retains all observations(Antonakakis, Chatziantoniou, & Gabauer, 2020). These advantages, confirmed through Monte Carlo simulations, ensure more reliable and dynamic estimations of connectedness. The findings of this study have significant implications for investors and portfolio managers engaged in Indian equity markets. Firstly, analyzing the connectedness between the Indian equity sectors and alternative investments under different crises enables the timely adjustment of the allocation as well as the hedging effectiveness. This comprehensive analysis helps investors to make effective changes to their investment portfolios in response to market volatility. Further, the study examines the net

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directional pairwise spillover, which captures the direction and magnitude of spillover between asset classes. Through this, investors and fund managers can enhance their portfolios during tail events. The remainder of the paper is structured as follows: Section 2 outlines the methodology and data. Section 3 discusses empirical results. Section 4 concludes with key findings and practical implications for investors and policymakers.

2. Methodology

We employ the time-varying parameter vector autoregression (TVP-VAR) spillover dynamics model introduced by (Antonakakis et al., 2020) expressed in the following manner:

$$z_t = B_t z_{t-1} + \mu_t \qquad \mu_t : N(0, S_t) \qquad\qquad Eq(1)$$

$$vec\,(B_t) = vec(B_{t-1}) + v_t \qquad v_t : N(0, R_t) \qquad\qquad Eq(2)$$

$$\tilde{\phi}_{ij,t}(H) = \frac{\sum_{t=1}^{H-1} \psi_{ij,t}^2}{\sum_{j=1}^{m} \sum_{t=1}^{H-1} \psi_{ij,t}^2} \qquad\qquad Eq(3)$$

The generalized variance decomposition approach developed by Koop et al., (1996) and Pesaran & Shin, (1998), and the H-step-ahead forecast is given equation 3. The total connectedness index is constructed is as follows,

$$K_t(H) = \frac{\sum_{i,j=1,i\neq j}^{m} \tilde{\phi}_{ij,t}(H)}{\sum_{i,j=1}^{m} \tilde{\phi}_{ij,t}(H)} * 100 = \frac{\sum_{i,j=1,i\neq j}^{m} \tilde{\phi}_{ij,t}(H)}{m} * 100. \qquad\qquad Eq(4)$$

Transmittance of shocks from one variable to another is illustrated by the connectedness approach. To commence, we analyze the situation in which the shock applied to the variable *i* is transmitted to all other variables *j*. The term total directional connectedness to others is used to describe this phenomenon.

$$K_{i\rightarrow j,t}(H) = \frac{\sum_{j=1,i\neq j}^{m} \tilde{\phi}_{ji,t}(H)}{\sum_{j=1}^{m} \tilde{\phi}_{ji,t}(H)} * 100. \qquad\qquad Eq(5)$$

Subsequently, we calculate the directional connectedness of variable i from variable j, denoted as the total directional connectedness from others and generally defined as follows:

$$K_{i\leftarrow j,t}(H) = \frac{\sum_{j=1,i\neq j}^{m} \tilde{\phi}_{ij,t}(H)}{\sum_{i=1}^{m} \tilde{\phi}_{ij,t}(H)} * 100. \qquad\qquad Eq(6)$$

The net directional connectedness from market i to all other markets j is represented as $K_{i,t}$ in this context.

$$K_{i,t} = K_{i\rightarrow j,t}(H) - K_{i\leftarrow j,t}(H) \qquad\qquad Eq(7)$$

Ultimately, the measure of net pairwise connectedness from market i to market j is determined.

$$NPDC_{ij}(H) = (\tilde{\phi}_{jit}(H) - \tilde{\phi}_{ijt}(H)) * 100. \qquad Eq(8)$$

If the value of NPDCij(H) is greater than zero (less than zero), it indicates that variable i dominates (is dominated by) variable j.

2.1. Hedge Strategy Framework

Following Kroner & Sultan (1993), the optimal hedge ratio (β_{mnt}) for a two-asset portfolio is calculated as follows:

$$\beta_{mnt} = \frac{h_{mnt}}{h_{nnt}}$$

where h_{mnt} is the conditional covariance of variable m and n. This implies that higher conditional variances lead to lower long-position hedging costs, whereas an increase in conditional covariances will increase the long-position hedging costs. The optimal portfolio weights between equity asset classes and alternative investments can be obtained when the risk is minimal, and the formula follows (Kenneth F. Kroner & Ng, 1998)

$$w_{mn} = \frac{h_{nn} - h_{mn}}{h_{mm} - 2h_{mn} + h_{nn}}$$

with

$$w_{mn} = \begin{cases} 0, & 0 < w_{mn} \\ w_{mn,} & 0 \leq w_{mn} \leq 1 \\ 1, & w_{mn} > 1 \end{cases}$$

We can also get the hedge effectiveness (HE) as follows:

$$HE_{mn} = \frac{h_{unhedged} - h_{hedged}}{h_{unhedged}}$$

where $h_{unhedged}$ represents the conditional variance of assets without hedging strategies, and h_{hedged} is the total variance of the hedged portfolio with the optimal investment weights.

3. Data analysis and empirical results

The study utilizes a dataset comprised of daily time series data on closing prices for the broad market index, BSE SENSEX, along with its sectoral indices: S&P BSE Commodities (SPBC), S&P BSE Consumer Discretionary (SPBCD), S&P BSE Energy (SPBE), S&P BSE Fast Moving Consumer Goods (SPBF), S&P BSE Financial Services (SPBFS), S&P BSE Healthcare (SPBH), S&P BSE Industrials (SPBI), S&P BSE Information Technology (SPBIT), S&P BSE Telecommunication (SPBT), and S&P BSE Utilities (SPBU). Additionally, the dataset includes daily closing prices for alternative investments under investigation: gold, crude oil (West Texas Intermediate Price - WTI), and the OVX, which reflects the market's 30-day forward-looking expectation of oil volatility. To capture the cryptocurrency market dynamics, the CCI 30 index, sourced from https://cci30.com/, is employed as an alternative proxy, consisting of the 30 largest cryptocurrencies by market capitalization. Alternative investment data

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was obtained from the Bloomberg database. The stock market data has been collected from the BSE website on a daily basis and segmented into three panels based on the occurrence of substantial events. These events include the onset of the COVID-19 pandemic in January 2020, followed by the Russia-Ukraine War in February 2022. In conclusion, this study covers the whole period from January 2015 to February 2024 based on the data availability of the cryptocurrency index. The three panels are as follows:

- Panel A: Covid-19 Pandemic - (January 2020 to January 2022)
- Panel B: Russia-Ukraine War - (February 2022 to February 2023)
- Panel C: Full Period - (January 2015 to February 2024)

Figure 1 illustrates the fluctuation patterns of all the variables' returns. The Indian benchmark index and sectors returns and gold, oil, OVX, and cryptocurrency returns experienced significant impacts from the heightened uncertainty stemming from the COVID-19 pandemic. Throughout the observed period, SPBU, SPBIT, gold, and CCI.30 exhibited high levels of volatility, contrasting with the relatively lower volatility observed in oil, OVX, SPBSX, SPBCD, SPBF, and SPBFS.
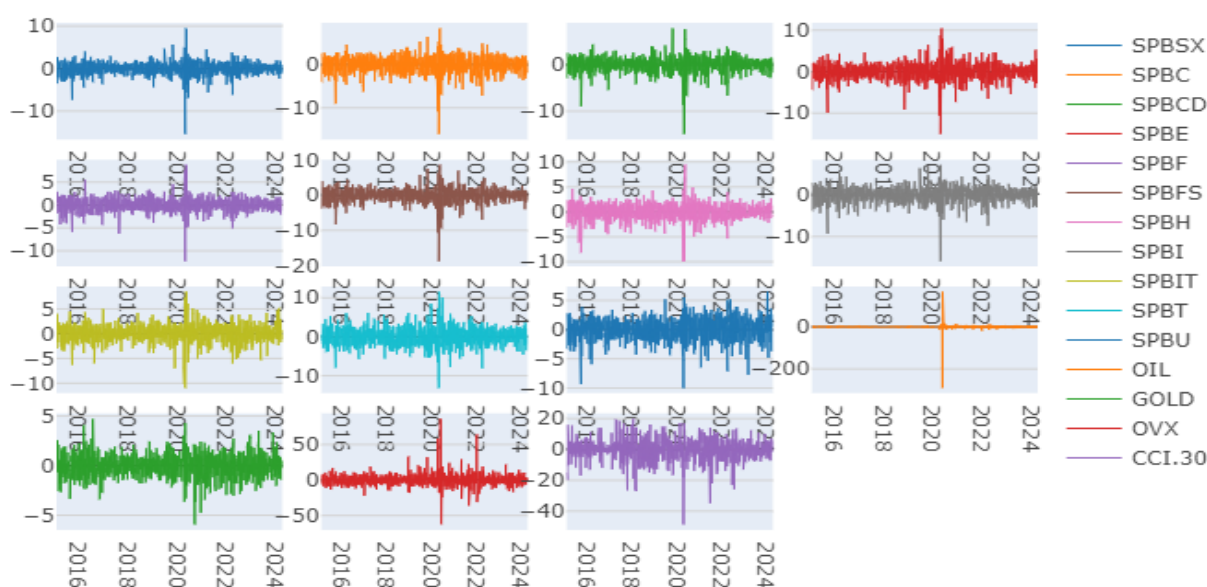

Figure 1. Dynamics of asset returns. Source: Authors' estimation

Table 1 provides a comprehensive view of the performance of the Indian benchmark equity with sectoral indices and other assets during the entire period. The mean values indicate average returns. CCI.30 shows the highest return, highlighting crypto's growth. Oil and OVX have negative returns, while sector indices like SPBE and SPBI performed better than SPBT, the lowest. Notably, the CCI.30, representing the cryptocurrency market, displayed the most robust performance with returns of 22%. It is important to note that the Oil, OVX and CCI.30 showed high volatility. At the same time, the benchmark and sectoral indices demonstrated the lowest level of volatility among the assets. The data shows significant skewness and excess kurtosis across all assets, indicating non-normal return distributions. Most returns are negatively skewed (left-tailed), except OVX (positively skewed), and all exhibit heavy tails (leptokurtic), suggesting frequent extreme return events. The

Jarque-Bera test has led us to reject the null hypothesis of normality with a significance level of 1%, as all p-values obtained are virtually zero. Furthermore, our findings from the stationarity test reveal that, at the 1% significance level, all the series included in our study are stationary. This implies the rejection of the null hypothesis of non-stationarity for all the series examined in this study. Table 2 presents the unconditional correlation matrix, showcasing the relationships among the examined financial instruments and indices. Noteworthy findings include the robust positive correlations within sectors, indicating synchronized movements between the broad market index (SPBSX) and its sectoral counterparts (SPBC, SPBCD, SPBE, SPBF, SPBFS, SPBH, SPBI, SPBIT, SPBT, SPBU), underscoring sector-specific influences on market dynamics. Additionally, moderate to strong positive correlations between different sectoral indices highlight interdependencies within the Indian market. Conversely, alternative investments like oil and gold exhibit weak correlations with equity indices, indicating limited association between these asset classes. Oil and SPBH are least correlated because global economic and geopolitical factors drive oil, while SPBH (healthcare) is a defensive sector and less sensitive to such shocks. However, the results are not significant. Gold is slightly more correlated to SPBH as both act as safe-haven assets, attracting investors during market uncertainty and economic downturns. The negative correlations of the OVX with most assets suggest that heightened oil volatility tends to coincide with declines in other asset prices. Notably, the CCI 30 index, representing cryptocurrencies, demonstrates weak to moderate positive correlations with traditional equity indices, implying some degree of association between cryptocurrency market movements and broader market trends.

Table 3 outlines the dynamic interconnections between returns across various equity asset classes within the Indian stock market and alternative investments. Notably, SPBCD, SPBI, and SPBC emerge as significant conduits of spillovers, transmitting and receiving influences from other sectors. This finding aligns with the research by (Al-Nassar, Boubaker, Chaibi, & Makram, 2023; Sang Hoon Kang et al., 2023; Walid Mensi, Nekhili, Vo, Suleman, & Kang, 2021), which underscores the pivotal role of consumer discretionary and industrial sectors in propagating spillovers to other segments. These sectors hold allure for investors inclined towards risk-taking due to their spillover characteristics, hinting at potentially favourable outcomes during market upswings. However, it's crucial to note that they might also bear the brunt of downturns more acutely. Interestingly, among equity asset classes, the benchmark index, SPBSX, stands out as the main source of spillovers. It is recommended that investors in sectors such as SPBFS, SPBIT, and SPBF diligently observe the performance of the SPBSX in order to safeguard against potential losses, particularly those stemming from adverse trends in the SPBSX. On the contrary, investors who are considering SPBSX positions may also consider opportunities in indices like SPBT and SPBH, which provide spillover diversification, while SPBSX's impacts are comparatively less significant.

The SPBCD sector plays a key role in transmitting market movements (spillover effects) but has a limited direct impact on the SPBIT and SPBT sectors. However, it significantly influences the SPBI and SPBC indices. Therefore, investors in the SPBI, SPBC, and SPBFS sectors should closely monitor SPBCD to manage potential risks. Conversely, those interested in SPBCD may diversify their holdings into the SPBIT and SPBT sectors. Although the influence of these sectors extends to other indices, it is comparatively less pronounced on certain ones. Likewise, SPBI should be monitored by investors who hold SPBCD, SPBC, and SPBU to mitigate potential risks. Alternatively, SPBI investors may diversify into SPBIT and SPBT to increase their exposure.

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Table 1: Summary Statistics

	Mean	Variance	Skewness	Ex.Kurtosis	JB	ERS	Q(10)	Q2(10)
SPBSX	0.031	1.493	-1.341***	18.296***	32327.118***	-6.547***	22.096***	782.397***
SPBC	0.04	2.218	-1.161***	9.293***	8674.861***	-8.929***	19.408***	327.678***
SPBCD	0.041	1.588	-1.305***	13.595***	18116.324***	-13.835***	24.917***	316.273***
SPBE	0.056	2.457	-0.656***	9.661***	8987.357***	-19.355***	15.296***	770.860***
SPBF	0.029	1.312	-0.614***	11.766***	13232.001***	-14.076***	15.579***	574.155***
SPBFS	0.029	2.281	-1.284***	15.953***	24684.855***	-6.267***	29.322***	682.768***
SPBH	0.027	1.497	-0.672***	7.082***	4912.612***	-15.897***	15.516***	290.905***
SPBI	0.05	2.026	-1.251***	10.975***	11978.361***	-6.617***	36.587***	304.266***
SPBIT	0.045	1.914	-0.545***	6.768***	4442.167***	-8.321***	14.683***	624.596***
SPBT	0.012	2.97	0.03	5.419***	2777.003***	-19.817***	4.292	582.249***
SPBU	0.04	2.03	-0.786***	4.624***	2255.510***	-10.482***	30.024***	349.936***
OIL	-0.02	88.028	-14.237***	543.888***	28043439.2***	-19.968***	557.492***	932.941***
GOLD	0.024	0.772	-0.213***	3.190***	979.414***	-11.491***	11.157**	96.817***
OVX	-0.024	38.52	1.817***	31.144***	92947.096***	-23.132***	16.371***	149.049***
CCI.30	0.221	24.05	-1.101***	8.613***	7471.762***	-20.169***	22.555***	100.648***

Notes: ***, **, and * signify statistical significance at the 1%, 5%, and 10% level; Source: Author's estimation

Table 2: Unconditional Correlation

	SPBSX	SPBC	SPBCD	SPBE	SPBF	SPBFS	SPBH	SPBI	SPBIT	SPBT	SPBU	OIL	GOLD	OVX	CCI 30
SPBSX	1***														
SPBC	0.83***	1***													
SPBCD	0.88***	0.86***	1***												
SPBE	0.77***	0.7***	0.71***	1***											
SPBF	0.77***	0.67***	0.74***	0.58***	1***										
SPBFS	0.94***	0.8***	0.84***	0.66***	0.66***	1***									
SPBH	0.67***	0.69***	0.69***	0.55***	0.61***	0.6***	1***								
SPBI	0.85***	0.88***	0.89***	0.69***	0.69***	0.83***	0.68***	1***							
SPBIT	0.68***	0.52***	0.55***	0.47***	0.48***	0.51***	0.47***	0.52***	1***						
SPBT	0.61***	0.6***	0.59***	0.48***	0.5***	0.55***	0.49***	0.59***	0.39***	1***					
SPBU	0.7***	0.77***	0.73***	0.65***	0.58***	0.67***	0.59***	0.76***	0.43***	0.53***	1***				
OIL	0.1***	0.09***	0.09***	0.08***	0.06***	0.09***	0.03	0.08***	0.08***	0.05**	0.07***	1***			
GOLD	0.03*	0.04*	0.03	0.02	0.03	0.02	0.07***	0.03	0.05**	0.03	0.05**	0.04**	1***		
OVX	-0.22***	-0.19***	-0.19***	-0.19***	-0.17***	-0.2***	-0.15***	-0.19***	-0.14***	-0.18***	-0.16***	-0.38***	0.01	1***	
CCI 30	0.11***	0.11***	0.09***	0.08***	0.07***	0.1***	0.1***	0.09***	0.1***	0.07***	0.08***	0.03	0.08***	-0.09***	1***

Notes: ***, **, and * signify statistical significance at the 1%, 5%, and 10% level; Source: Author's estimation

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Table 3: Time-varying Total Connectedness Index for the full period

	SPBSX	SPBC	SPBCD	SPBE	SPBF	SPBFS	SPBH	SPBI	SPBIT	SPBT	SPBU	OIL	GOLD	OVX	CCI 30	FROM
SPBSX	15.09	9.17	10.43	7.84	8.00	12.79	5.98	9.92	5.61	5.03	7.01	0.77	0.75	0.89	0.72	84.91
SPBC	10.04	16.43	11.32	7.16	6.22	9.30	6.83	11.40	3.46	5.40	9.32	0.73	0.79	0.86	0.73	83.57
SPBCD	10.88	10.75	15.88	6.74	7.44	9.78	6.93	11.61	3.62	5.37	8.19	0.69	0.69	0.79	0.65	84.12
SPBE	11.16	9.11	9.22	22.17	5.81	7.79	5.47	8.57	3.68	4.70	8.63	0.94	0.92	1.08	0.75	77.83
SPBF	11.45	7.92	10.09	5.94	22.53	8.28	6.39	8.63	3.65	4.84	6.53	0.98	0.87	1.04	0.84	77.47
SPBFS	14.52	9.57	10.53	6.37	6.65	17.23	5.51	10.58	3.24	4.79	7.27	1.09	0.90	0.98	0.77	82.77
SPBH	8.76	9.08	9.63	5.72	6.66	7.16	23.61	9.16	4.18	4.64	7.13	1.13	1.02	0.89	1.22	76.39
SPBI	10.49	11.01	11.84	6.42	6.55	9.93	6.66	16.10	3.26	5.45	8.75	0.99	0.92	0.85	0.78	83.90
SPBIT	11.24	5.95	6.63	4.85	4.89	5.29	5.28	5.70	36.01	3.76	4.40	1.63	1.71	1.50	1.16	63.99
SPBT	8.52	8.21	8.53	5.81	5.70	7.05	5.45	8.55	3.34	27.76	6.80	1.17	0.93	1.15	1.01	72.24
SPBU	8.93	11.02	10.06	8.03	5.95	8.27	6.14	10.66	2.80	5.27	19.97	0.72	0.71	0.80	0.66	80.03
OIL	2.25	2.10	2.01	1.70	1.92	2.24	2.37	2.11	1.60	1.97	1.87	60.46	2.78	12.81	1.80	39.54
GOLD	2.48	2.29	2.30	2.29	2.07	2.45	1.94	2.65	2.34	1.95	2.12	3.45	66.81	2.60	2.24	33.19
OVX	2.84	2.31	2.40	2.20	2.20	2.94	1.92	2.31	2.15	2.06	1.98	13.10	2.32	57.16	2.11	42.84
CCI 30	2.30	2.39	2.21	1.76	2.40	2.23	2.37	2.36	2.02	2.19	2.06	2.11	2.20	2.26	69.13	30.87
TO	115.86	100.90	107.22	72.83	72.48	95.51	69.26	104.22	44.95	57.44	82.05	29.50	17.53	28.48	15.44	1013.66
Inc.Own	130.95	117.33	123.10	95.00	95.01	112.74	92.87	120.31	80.96	85.21	102.02	89.96	84.34	85.64	84.56	cTCI/TCI
NET	30.95	17.33	23.10	-5.00	-4.99	12.74	-7.13	20.31	-19.04	-14.79	2.02	-10.04	-15.66	-14.36	-15.44	72.40/67.58
NPT	14.00	11.00	13.00	8.00	7.00	10.00	6.00	12.00	3.00	5.00	9.00	4.00	0.00	2.00	1.00	

Source: Author's estimation

SPBC indices rank in the upper three percentages for spillover reception and transmission. Their influence on the SPBIT, SPBF, and SPBT sectors is negligible, whereas they significantly impact the SPBU, SPBI, and SPBCD indices. To safeguard against potential losses, SPBC performance must be closely monitored by investors, particularly those with holdings in the SPBU, SPBI, and SPBCD sectors. On the contrary, SPBC investors can consider the benefits of diversification by examining investments in the SPBIT, SPBF, and SPBT industries. SPBFS, SPBI, SPBC, SPBCD, SPBU, and SPBCD are indices whose performance should be closely monitored by investors to determine whether they have a substantial impact on their investments. This will assist them in safeguarding against any possible negative consequences. On the other hand, investors in these important sectors can take advantage of diversification benefits by considering investment opportunities in sectors with lower spillover effects, like SPBIT, SPBF, and SPBT. All alternative investments exhibit lower connectedness with the Indian equity index and sectoral indices. Oil demonstrates significant spillover to SPBIT, SPBT, and SPBH while showing less influence on SPBU, SPBC, and SPBSX. Conversely, it receives more spillover from SPBSX, SPBFS, and SPBH and less from SPBIT, SPBE, and SPBU.

Similarly, OVX transmits high spillover to SPBIT, SPBT, and SPBU, with minimal impact on SPBU, SPBI, and SPBC, while receiving larger spillover from SPBFS and SPBSX but less from SPBH and SPBU. Gold channels have high spillover to SPBIT and SPBH and less to SPBU and SPBSX, yet it receive more spillover from SPBI, SPBSX, and SPBFS and less from SPBH and SPBT. These findings show that all the investigated alternative investment assets act as expensive hedges during crisis periods, aligning with the results of Akhtaruzzaman, Boubaker, & Sensoy (2021) and Ustaoglu, (2022). However there is another stand of literature shows that gold is treated as flight-to-safety asset, especially during crisis periods (Akhtaruzzaman, Boubaker, & Sensoy, 2021b; Al-Yahyaee, Mensi, Sensoy, & Kang, 2019). Meanwhile, cryptocurrency transmits high spillover to SPBH, SPBIT, and SPBT and less to SPBCD and SPBU. Nevertheless, it receives more spillover from SPBF, SPBC, and SPBH and less from SPBE, SPBIT, and SPBU. These are aligns with previous studies (Yousaf & Yarovaya, 2022) that connectedness between the equity sector and cryptocurrency were least.

These dynamics underscore the intricate interconnectedness between alternative investments and equity indices, highlighting the importance of diversification strategies in portfolio management. This visualization of net pairwise directional connectedness highlights the direction and intensity of volatility shifts among these assets. The size of each circle indicates its impact on spillover effects. Each circle depicted in blue or dark grey initiate volatility transfers, while those in yellow or light grey receive such transfers.

Arrows between circles represent the volatility flow, with arrow thickness reflecting the magnitude of net volatility transfer. In Figure 2, during the COVID-19 pandemic, the directional connectedness between equity asset classes and alternative investments like gold, oil, OVX, and cryptocurrency demonstrates a robust interplay. Notably, SPBSX emerges as the predominant transmitter of risk, particularly towards SPBIT and SPBT. Other significant transmitters include SPBC, SPBCD, and SPBI. Conversely, oil and CCI.30 emerge as primary receivers of risk, while among equity classes, SPBE and SPBFS exhibit minimal risk transmission, with SPBF and SPBH being the least affected as receivers. In Figure 3, the connectedness between equity asset classes and alternative investments remains strong amidst the Russia-Ukraine war. SPBSX continues to be the main transmitter of risk, notably towards SPBIT, with SPBCD, SPBC, and SPBI also playing significant roles. Gold, OVX, CCI.30, and oil emerge as primary receivers of risk. SPBE and SPBFS exhibit minimal

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risk transmission among equity classes, while SPBT and SPBU are least affected as receivers. In Figure 4, over the entire period, SPBSX remains a significant transmitter of risk towards SPBIT, SPBF, and SPBT, with SPBCD and SPBC also transmitting substantial risk. Conversely, SPBIT, CCI.30, OVX, oil, and gold are primary receivers of risk. Among equity asset classes, SPBU and SPBI exhibit minimal risk transmission, while SPBF and SPBE are the least affected as receivers.
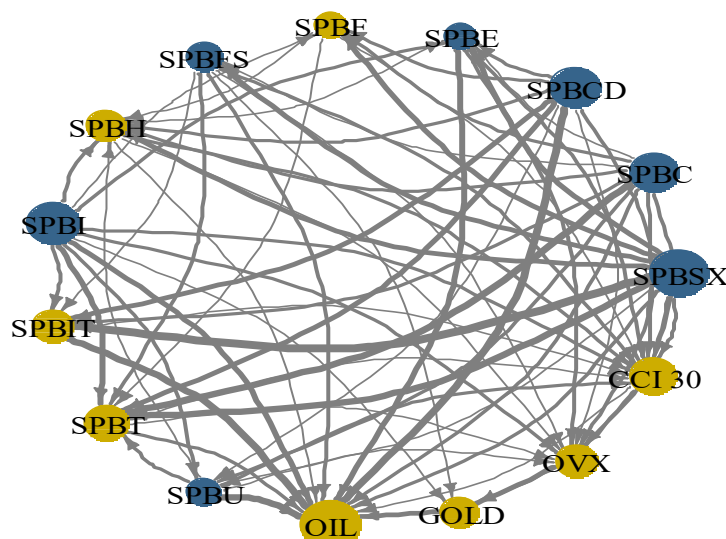

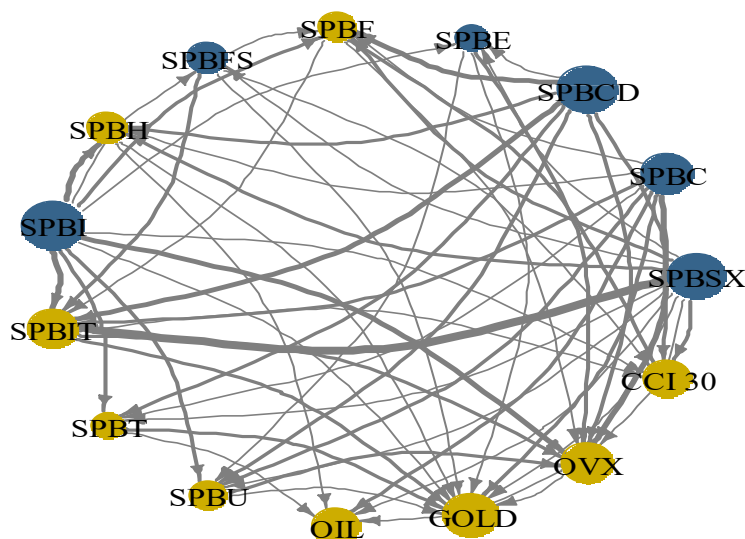Figure 2: Net pairwise directional connectedness – COVID-19

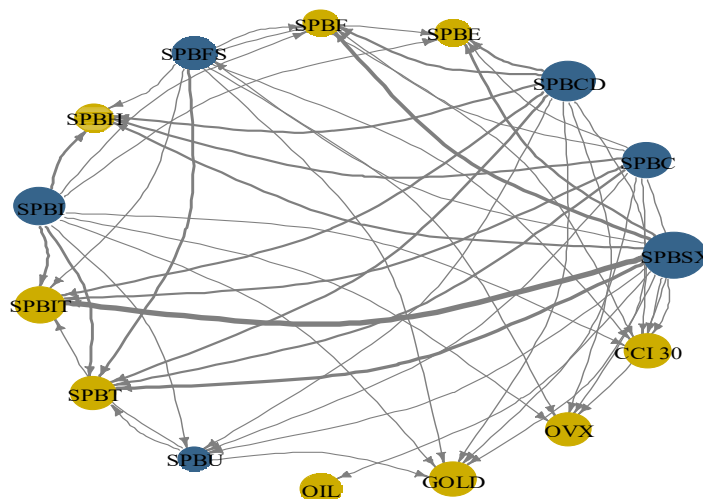Figure 3: Net pairwise directional connectedness – Russia-Ukraine War

Figure 4: Net pairwise directional connectedness – Full Period
Source: Author's estimation

Finally, we examine the hedging performance of gold, oil, OVX, and CCI.30 in Indian equity benchmarks and sectoral indices. Table 4 presents the optimal portfolio weights, hedge ratios, and hedging effectiveness (HE) of the Indian equity benchmark and sectoral indices returns concerning gold, oil, OVX, and CCI.30. The calculated portfolio weights denote the allocation of assets within the portfolio, while the hedge ratios quantify the extent of hedging against adverse effects. The optimal weights for gold range from 20% to 37%, while oil, OVX, and CCI.30 range from 90% to 99%. Notably, the optimal allocation for the SPBF/GOLD pair is 0.37. This implies that, for every $1 of investment, an investor in the SPBF equity sector should allocate 37 cents to gold and the remaining 63 cents to the paired sector. Gold proves to be an effective hedging option, with effectiveness ranging from 62% to 79% for the Indian market and sector indices. All the other alternative investments are minimally weighted in the equity market except for gold. This allocation strategy aims to minimize risk while maintaining the expected return unchanged. Similar interpretations apply to the other pairs.

The hedge ratios are positive for all portfolios hedged with gold, but with oil and CCI.30, it was nearing Zero. However, hedge ratios are also negative in the case of OVX; therefore, a hedge can be performed using long positions in equities and OVX. The hedging effectiveness values favour the construction of mixed portfolios to diversify downside risk better. A higher HE ratio denotes stronger hedging effectiveness, indicating a greater reduction in portfolio variance compared to the benchmark portfolio. For example, the HE ratio of 0.65 in the SPBSX/GOLD pair indicates relatively robust hedging effectiveness. In contrast, the HE ratio of 0.00 in the SPBSX/OIL pair suggests minimal effectiveness in hedging against risk. Gold is the most effective hedge against the equity sector. Notably, oil and CCI.30 are the least effective hedges for the equity sectors. An illustration of this can be seen in the SPBSX/OIL pair, where a portfolio weight of 0.99 signifies a significant proportion of the investment in the SPBSX (the benchmark equity index of India) relative to oil. This is accompanied by a hedge ratio of 0.01, indicating that the level of protection against potential adverse effects is minimal. Conversely, in the case of SPBSX/GOLD, a hedge ratio of 0.04 and a portfolio weight of 0.34 indicate a diminished allocation to SPBSX compared to gold, respectively, and thus support an effective hedging strategy.

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Table 4: Portfolio hedging and optimization

	Portfolio weight	Hedge Ratio	HE
SPBSX/OIL	"0.99"	" 0.01"	"0.00"
SPBC/OIL	"0.99"	" 0.01"	"0.00"
SPBCD/OIL	"0.99"	" 0.01"	"0.00"
SPBE/OIL	"0.99"	" 0.01"	"0.01"
SPBF/OIL	"0.99"	" 0.01"	"0.00"
SPBFS/OIL	"0.99"	" 0.01"	"0.01"
SPBH/OIL	"0.99"	" 0.00"	"0.01"
SPBI/OIL	"0.99"	" 0.01"	"0.01"
SPBIT/OIL	"0.99"	" 0.01"	"0.00"
SPBT/OIL	"0.98"	" 0.01"	"0.02"
SPBU/OIL	"0.99"	" 0.01"	"0.01"
SPBSX/GOLD	"0.34"	" 0.04"	"0.65"
SPBC/GOLD	"0.26"	" 0.05"	"0.73"
SPBCD/GOLD	"0.33"	" 0.04"	"0.66"
SPBE/GOLD	"0.24"	" 0.03"	"0.76"
SPBF/GOLD	"0.37"	" 0.03"	"0.62"
SPBFS/GOLD	"0.25"	" 0.04"	"0.74"
SPBH/GOLD	"0.33"	" 0.08"	"0.64"
SPBI/GOLD	"0.28"	" 0.04"	"0.72"
SPBIT/GOLD	"0.28"	" 0.08"	"0.70"
SPBT/GOLD	"0.20"	" 0.06"	"0.79"
SPBU/GOLD	"0.27"	" 0.07"	"0.71"
SPBSX/OVX	"0.93"	"-0.04"	"0.15"
SPBC/OVX	"0.91"	"-0.05"	"0.16"
SPBCD/OVX	"0.93"	"-0.04"	"0.14"
SPBE/OVX	"0.90"	"-0.05"	"0.17"
SPBF/OVX	"0.94"	"-0.03"	"0.11"
SPBFS/OVX	"0.91"	"-0.05"	"0.17"
SPBH/OVX	"0.94"	"-0.03"	"0.11"
SPBI/OVX	"0.92"	"-0.04"	"0.15"
SPBIT/OVX	"0.93"	"-0.03"	"0.12"
SPBT/OVX	"0.89"	"-0.05"	"0.18"
SPBU/OVX	"0.92"	"-0.04"	"0.13"
SPBSX/CCI 30	"0.97"	" 0.03"	"0.02"
SPBC/CCI 30	"0.94"	" 0.03"	"0.04"
SPBCD/CCI 30	"0.96"	" 0.03"	"0.03"
SPBE/CCI 30	"0.93"	" 0.03"	"0.05"

SPBF/CCI 30	"0.96"	" 0.02"	"0.03"
SPBFS/CCI 30	"0.94"	" 0.03"	"0.04"
SPBH/CCI 30	"0.97"	" 0.03"	"0.02"
SPBI/CCI 30	"0.95"	" 0.03"	"0.04"
SPBIT/CCI 30	"0.95"	" 0.03"	"0.03"
SPBT/CCI 30	"0.91"	" 0.03"	"0.07"
SPBU/CCI 30	"0.94"	" 0.03"	"0.04"

Source: Authors' estimation

4. Conclusion

This study investigates the role of alternative asset classes—such as gold, oil, and cryptocurrency—as potential hedging instruments or diversifiers, particularly during times of crisis when sector-specific shocks and volatility transmission are more pronounced. Focusing on the Indian equity market, the research explores the dynamic interconnectedness between key alternative investments (gold, oil, the Crude Oil Volatility Index [OVX], and the CCI.30 cryptocurrency index) and the Indian benchmark index along with its sectoral indices over the past decade. This includes major crisis periods such as the COVID-19 pandemic (a global health crisis) and the Russia-Ukraine conflict (a geopolitical crisis). The study hypothesizes that these alternative assets can serve as effective tools for hedging or diversification against sector-specific risks. By examining their interrelationships with sectoral indices, the research provides valuable insights into strategies for mitigating portfolio risk in times of heightened uncertainty. We employ the TVP-VAR spillover index to examine the variations in returns and risk transfer across these markets. Our empirical results show SPBSX, SPBCD, SPBC, SPBFS, and SPBI consistently exhibit high levels of volatility during times of crisis and throughout the entire period. On the other hand, SPBF, SPBH, SPBIT, and SPBT consistently act as recipients of volatility in both situations. SPBE and SPBU play a dynamic role, serving as both transmitters and receivers. As an example, SPBE only transmits risk during crisis periods, rather than throughout the entire period. On the other hand, SPBU only receives risk during the Russia-Ukraine War period. Alternative investments such as gold, oil, OVX, and cryptocurrency show a consistent pattern of volatility transmissions from Indian equity and sectoral indices over different time periods. Amidst the COVID-19 pandemic, there was a notable increase in volatility for CCI.30, oil, and OVX, whereas gold remained relatively stable. On the other hand, gold was greatly affected by the Russia-Ukraine War, while OVX and CCI.30 also experienced significant volatility. Oil, however, remained relatively stable during this period. During the full period, CCI.30 experienced the highest level of volatility, with gold and OVX following closely behind. On the other hand, oil experienced relatively low volatility transmission. Gold is the most effective hedge, whereas oil and CCI.30 are the least effective hedges against the equity sectors. The aforementioned finds offer significant perspectives on the optimal approach for asset allocation and the efficacy of hedging tactics in mitigating risk. This information can assist investors in making informed decisions regarding portfolio construction and risk management. In addition to precise estimation of the spillover index and dynamic risk-minimizing hedge ratios, a comprehensive understanding of portfolio dynamics is crucial for optimizing portfolio performance and managing risk exposure effectively. However, the scope of this

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study is limited to the Indian equity market and a select set of alternative assets—gold, oil, OVX, and CCI.30. Future research could extend this framework by incorporating additional strategic commodities and exploring other emerging and developed markets. Such an expansion would enable a broader perspective on the global dynamics of volatility transmission and the comparative effectiveness of hedging strategies across different market conditions.

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