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The Impact of Uncertainty Indices on The Spillover Effects in The Global Commodity Market

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Abstract. To explore the spillover relationships among commodity markets and the impacts of uncertainty index variables thereon, this paper employs the DY spillover approach to investigate the mean spillover effects across 10 sub-sectors of the commodity market. Additionally, 8 uncertainty index variables are selected for regression analysis based on the AR model, aiming to examine how these uncertainty indices affect the mean spillovers among commodity markets. The empirical findings are as follows: first, the oil and meals sector acts as the primary risk transmitter in the commodity market, with the largest net spillover index value, thus making the most significant contribution to market interconnectedness; second, only the VIX exerts a statistically significant positive impact on the commodity market. This phenomenon may be attributed to the fact that a rise in the panic index could trigger speculative sentiment, prompting investors to engage in short-term trading or speculative activities. Consequently, such behaviors would lead to an increase in trading volume and severe price fluctuations in the commodity market.

Keywords: commodity markets; uncertainty factors.

1. Introduction

The interconnectedness among commodity market segments has become increasingly prominent, with risk spillover effects emerging as a key factor affecting market stability. Despite growing research on commodity market spillovers, existing studies have limitations: most focus on single-category spillovers (e.g., energy or agricultural products) or adopt static analysis, lacking dynamic and panoramic insights into cross-subsegment relationships. Meanwhile, prior research on uncertainty factors has mainly focused on economic policy uncertainty (EPU) and trade policy uncertainty (TPU), with insufficient analysis of the heterogeneous impacts of multi-dimensional indices (e.g., VIX, EUI, CPU) on spillovers. Thus, the mechanism by which uncertainty factors act on spillover effects remains unclear.

Against this backdrop, this study aims to address these gaps by exploring mean spillover relationships across ten commodity sub-segments (e.g., Energy, Beverages, Oils & Meals) and clarifying the heterogeneous impacts of eight uncertainty indices.

2. Literature References

Against the backdrop of the deepening process of global economic integration, the commodity market has evolved into a crucial area of focus for investors. Furthermore, with the continuous deepening of commodity financialization, the trend of price linkage among commodities has been on the rise (Ohashi and Okimoto, 2016)[1]. Given that scholars generally regard the energy market as the most volatile segment within the broader commodity market, numerous studies have explored the spillover effects among different types of energy products (Bouria et al., 2021)[2]. Lin & Li (2015) [3]conducted a regional segmentation of the crude oil and natural gas markets in the United States, Europe, and Japan, and examined different natural gas pricing mechanisms to investigate the price and volatility spillover effects across regional oil and natural gas markets.

Beyond the spillover effects within the energy sector, the interconnectedness between energy commodities and other non-energy commodity categories has also attracted increasing academic

attention, leading to a growing body of literature focusing on the spillover effects between energy and non-energy commodities such as agricultural products and precious metals (Ni et al., 2024; Xu et al., 2024)[4,5]. Specifically, Mensi et al. (2025)[6] tested the dependence structure and risk spillover relationship between crude oil and the futures of eight major agricultural products. The results indicated that there exists significant crisis sensitivity and time dependence between the oil and agricultural product markets.

In addition to the price linkage effects among different types of commodities, the dynamic relationship between uncertainty factors and commodity markets has also become a prominent topic in academic research, with a large number of relevant studies having been conducted. At present, the literature exploring the dynamic relationship between uncertainty and commodity markets is extensive. However, many scholars have focused on the relationships between economic policy uncertainty (EPU), trade policy uncertainty (TPU), monetary policy uncertainty (MPU) and commodity markets（Assaf et al., 2021; Oliyide et al., 2021) [8,9]. For instance, Yang et al. (2022)[7]employed a time-varying parameter autoregressive model with stochastic volatility to verify the time-varying impact of TPU on aggregate commodities. During the sample period from February 2000 to August 2021, the impact was short-term before 2006 and evolved into a medium-to-long-term one thereafter. Based on a wavelet-based variance decomposition model, Zhu et al. (2021)[10]investigated the correlation between economic policy uncertainty and the Chinese commodity market, and found that the contribution of EPU to the commodity futures market increased significantly during the financial crisis. Furthermore, within the same crisis period, the contribution of EPU varied across different sectors, with the grain sector being highly affected by EPU. From a global perspective, Li and Mu (2015) [11]analyzed the price fluctuations in the international commodity market and their influencing factors, and conducted a comparison between developed and emerging market economies. They concluded that the interest rate policies of developed countries and the monetary policies of emerging market economies are important drivers of commodity price volatility.

3. Data

3.1. Data Sources

To investigate the cross-category impacts within the commodity market, this paper divides the overall market into ten sub-sectors, namely Energy, Beverages, Oils & Meals, Grains, Other Food, Timber, Other Raw Materials, Fertilizers, Metals & Minerals, and Precious Metals. The commodity price index data for each sub-sector are retrieved from the World Bank, with a sample period spanning from February 1960 to December 2023.

A total of eight uncertainty index variables are selected to examine their impacts on the spillover relationships across the commodity market. These variables are specified as follows: the Global Economic Policy Uncertainty (GEPU), Energy-related Uncertainty Index (EUI), Geopolitical Risk (GPR), US Economic Policy Uncertainty (USEPU), Climate Policy Uncertainty (CPU), Crude Oil Price Uncertainty (OPU), CBOE Crude Oil ETF Volatility Index (OVX), and Volatility Index (VIX). Among these indicators, the data for GEPU, EUI, GPR, USEPU, CPU, and OPU are sourced from the Economic Policy Uncertainty Index Database, while the data for OVX and VIX are obtained from the Chicago Board Options Exchange (CBOE).

Given the discrepancies in the sample periods of the eight uncertainty indices, the corresponding time-span of the total spillover index is matched for each regression analysis to ensure temporal consistency. The specific sample periods for each uncertainty index are listed as follows:GEPU: February 1997-December 2023; EUI: February 1996-October 2022; GPR: February 1985-December 2023; USEPU: February 1985-December 2023; CPU: April 1987-December 2023; OPU: April 1979-December 2019; OVX: October 2009-December 2023; VIX: January 1990-December 2023.

3.2. Descriptive Statistics

Descriptive statistics and stationarity tests are conducted on the eight uncertainty indices required for this paper. For the stationary data, the values are divided by 100 to achieve the unification of data dimensions. For the non-stationary data, logarithmic differences are first calculated, followed by a second round of stationarity tests. The results of the descriptive statistics and stationarity tests are presented in the following table:

Table 3.1 Descriptive Statistics

	TCI	OVX	VIX	CPU	EUIG	GEPU	USEPU	OPU	GPR
Mean	0.000308	3.74E-02	1.96E-02	0.003878	0.020144	1.402698	0.123461	0.012549	0.000696
Median	-1.84E-05	0.034698	0.017753	0.017224	0.020519	1.172247	0.108009	-0.034135	-0.006711
Maximum	0.357847	0.163652	0.062669	1.232682	0.050659	4.315649	0.503963	3.629615	2.051304
Minimum	-0.18611	0.016678	0.010125	-1.701375	0.000359	0.492246	0.044783	-3.663081	-0.825669
Std.Dev.	0.020396	0.016081	0.007552	0.361801	0.009522	0.750342	0.057229	0.76356	0.23151
Skewness	8.044334	4.040363	1.989698	-0.176493	0.155113	1.134538	2.24518	0.219397	1.864253
Kurtosis	181.7999	29.09726	9.638169	3.802536	3.071733	3.679365	11.35719	5.775892	17.16881
Jarque-Bera	757364	5317.85	1018.315	14.09216	1.258869	75.73825	1755.115	160.9241	4176.866

As can be seen from Table 3.1, the means of all eight uncertainty index variables are relatively small, with the crude oil price uncertainty (OPU) exhibiting the largest standard deviation. The results of skewness, kurtosis, and Jarque-Bera tests indicate that the time series of the eight uncertainty indices conform to the distribution characteristic of leptokurtosis and fat tails.

4. Empirical Research

4.1. Static Spillover Analysis

Table 4.1 Static Spillover Matrix

	energy	beverages	oils&meals	grains	other.food	timber	other.raw.mat	fertilizers	metals&minerals	precious.metal	FROM others
energy	70.42	1.77	2.62	1.84	1.27	1.55	5.8	6.44	5.95	2.34	29.58
beverages	2.23	81.52	2.98	0.66	1.68	1.65	2.02	1.75	3.55	1.96	18.48
oils&meals	1.6	2.85	68.03	11.54	1.76	1.15	4.71	0.13	4.75	3.47	31.97
grains	0.72	0.7	18.6	69.12	1.64	0.57	3.71	0.2	2.36	2.38	30.88
other.food	1.59	1.45	3.82	3.48	80.04	0.33	1.71	1.22	3.12	3.25	19.96
timber	1.06	0.52	0.9	0.49	0.16	91.34	2.43	0.55	0.6	1.95	8.66
other.raw.mat	3.07	1.91	8.87	4.63	0.66	0.83	61.83	0.29	13.36	4.54	38.17
fertilizers	8.76	1.08	3.26	3.61	0.63	1.49	1.14	77.56	1.27	1.18	22.44
metals&minerals	4.5	2.33	5.11	2.28	1.58	0.85	7.49	0.1	68.07	7.69	31.93
precious.metal	2.48	1.91	4.32	1.11	3.11	2.19	3.13	0.82	6.28	74.65	25.35
TO others	26.01	14.52	50.47	29.66	12.51	10.61	32.14	11.51	41.21	28.77	257.41
Inc. own	96.43	96.04	118.5	98.77	92.55	101.96	93.97	89.07	109.29	103.42	TCI
NET	-3.57	-3.96	18.5	-1.23	-7.45	1.96	-6.03	-10.93	9.29	3.42	25.74

Table 4.1 presents the static spillover relationships among commodity markets. As indicated by the table, Oils & Meals exerts the most significant spillover impact on the entire commodity market, followed by Metals & Minerals, Other Raw Materials, and Grains. Among these sub-sectors, Oils & Meals and Metals & Minerals have positive net spillover indices, indicating that they are the primary contributors to the spillover effects in the commodity market. In contrast, Other Raw Materials is the most heavily influenced by the spillover effects across the commodity market, with the next most affected sub-sectors being Oils & Meals, Metals & Minerals, Grains, and Energy.

From the perspective of the direction and magnitude of volatility transmission, Oils & Meals exhibits the largest spillover magnitude to the Grains market. In descending order of magnitude, the next largest spillovers are Grains to Oils & Meals, Oils & Meals to Other Raw Materials, and Energy to Fertilizers. In other words, within the commodity market, Oils & Meals acts as the primary risk spillover transmitter, while Grains and Other Raw Materials are the main risk spillover receivers. With regard to the impact of Energy on other sub-sectors, Fertilizers is the most heavily influenced market.

4.2. Dynamic Spillover Analysis

4.2.1. Total Volatility Spillover

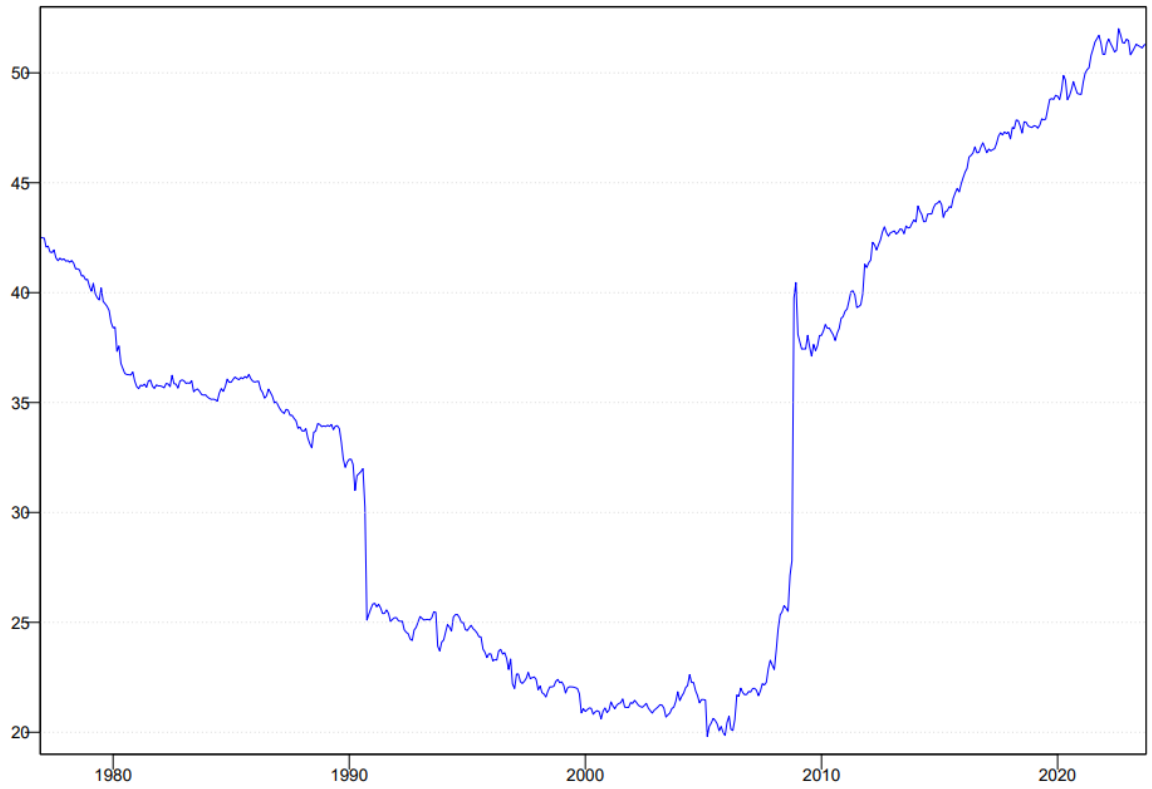

Figure 4.2.1 Total Spillover Index

Figure 4.2.1 plots a line chart of the total spillover index of the commodity market from 1960 to 2023, which reflects the interconnectedness and the degree of interaction among commodity markets. As can be observed from the figure, the total spillover index exhibits remarkably distinct time-varying characteristics. Its evolution can be divided into three distinct phases: first, a continuous decline in the total spillover index from 1960 to 1990; second, fluctuations of the Total Connectedness Index (TCI) at a relatively low level from 1990 to 2010; and third, an upward trend in the TCI since 2010.

The continuous decline in the total spillover index from 1960 to 1990 may be attributed to the gradual advancement of information technology and transportation technology. These technological improvements enhanced the efficiency and convenience of commodity production, trading, and transportation, which not only mitigated the impact of geographical distance but also reduced the interconnectedness among markets. From 1990 to 2010, the TCI fluctuated at a relatively low level, with a downward trend roughly from 1990 to 2008 and an upward trend from 2008 to 2010. The downward trend during the early period could be explained by the accelerating process of trade globalization after 1990, which led to the increasing diversification of commodity supply sources. Commodity supplies were no longer dependent on individual countries or regions, thereby weakening the linkages among markets. However, the 2008 global financial crisis spread to the commodity market, which strengthened the risk spillover relationships across markets and resulted in the subsequent upward trend of the TCI. Since 2010, the TCI has shown a consistent upward trend. This phenomenon may be due to the continuous financialization of the commodity market driven by the rise of the financial derivatives market. Investors can now conduct hedging and speculative transactions more flexibly, which has caused commodity price fluctuations to be increasingly influenced by financial factors and gradually strengthened the risk spillover relationships among markets.

4.2.2. Pairwise Volatility Spillover

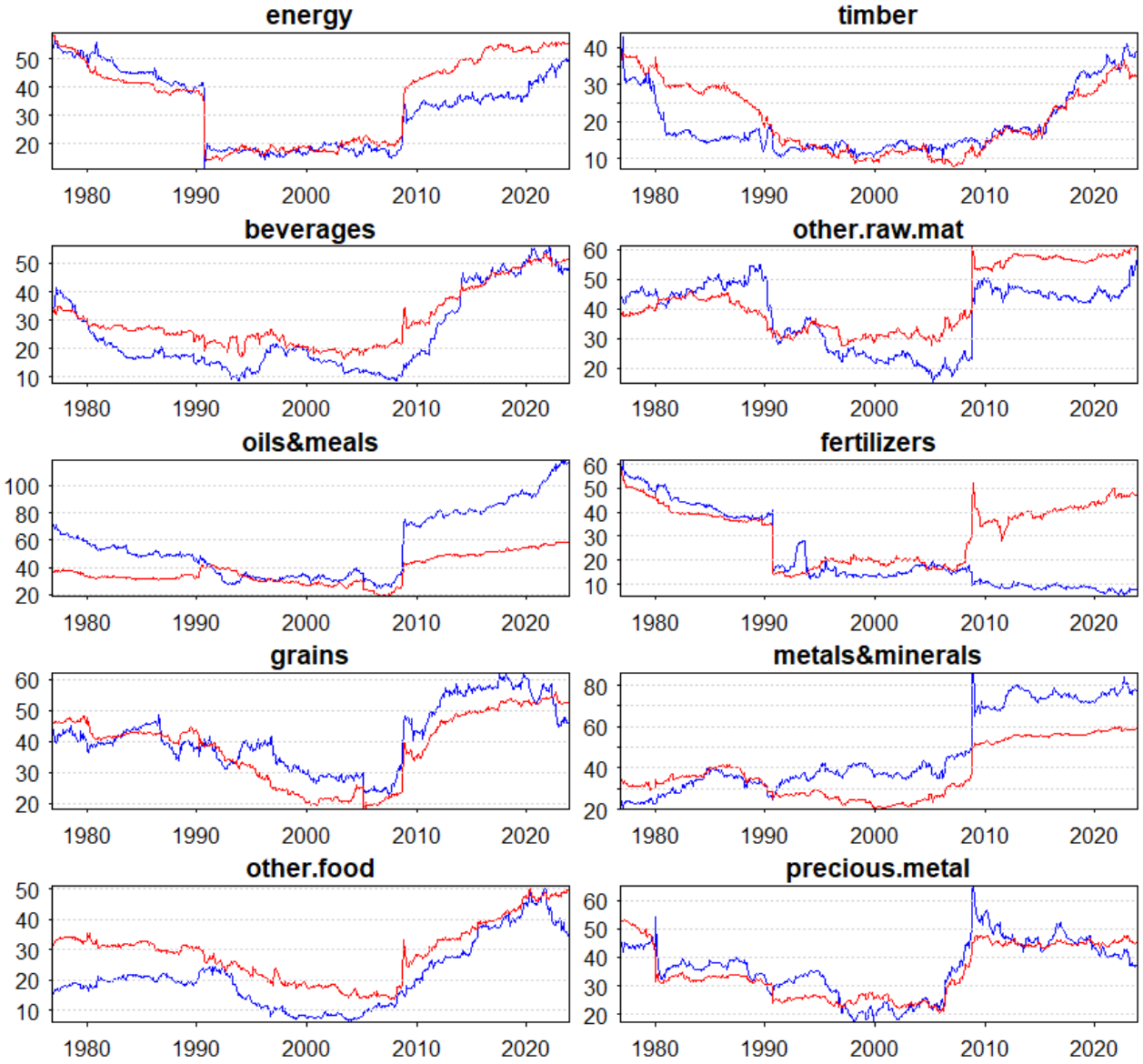

Figure 4.2.2 Line Chart of Dynamic Spillover Indices of the Commodity Market

Note: The red line represents the spillover index received by the sub-sector from other markets, while the blue line represents the spillover index transmitted by the sub-sector to other markets.

Pairwise volatility spillover indices consist of two directional volatility spillovers, which are asymmetric and can reveal more detailed information. As shown in Figure 4.2.2, the Metals & Minerals sub-sector had become a major risk transmitter after 1990. For Oils & Meals, the gap between its spillover to other sub-sectors and the spillover it received from other sub-sectors only began to widen gradually after 2010, and it thus emerged as a major risk transmitter. In contrast, for the Fertilizers and Energy sub-sectors, the gap between their spillover to other sub-sectors and the spillover they received from other sub-sectors only started to expand significantly after 2010, leading them to become major risk receivers.

4.2.3. Net Volatility Spillover

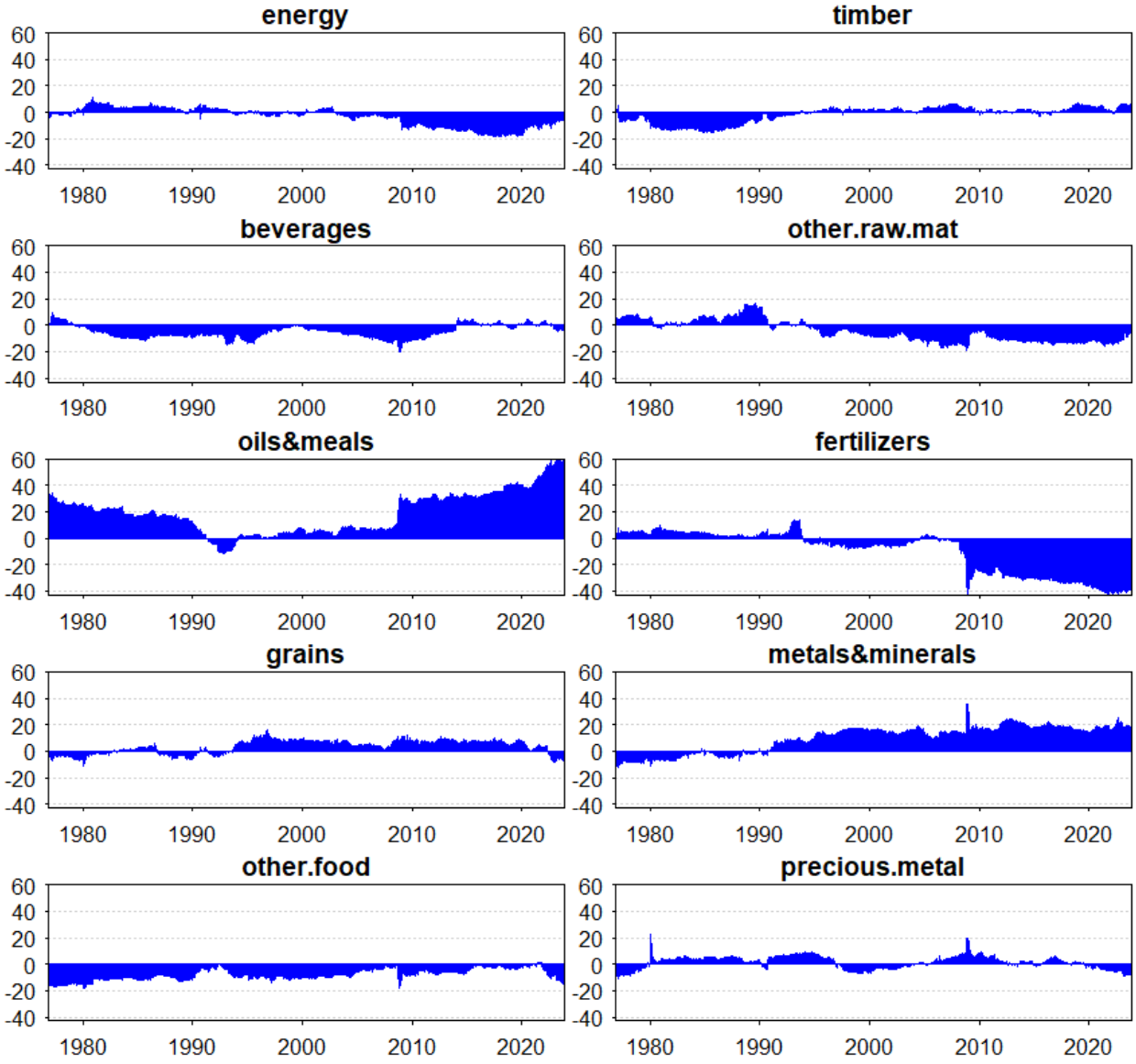

Figure 4.2.3 Dynamic Net Spillover Indices of the Commodity Market

Note: The net spillover index is calculated as the total spillover index of a sub-sector to other markets minus the spillover index it receives from other markets (to-from).

As can be seen from Figure 4.2.3, the Oils & Meals sub-sector exhibits the largest net spillover index, making the most significant contribution to market connectedness. The net spillover index of the Energy sub-sector has remained at a relatively low level, and has been consistently negative since 2010. This indicates that the Energy sub-sector has a low degree of correlation with other sub-sectors, and has been mainly influenced by other markets since 2010. The Precious Metals sub-sector experienced two separate spillover peaks in 1980 and 2010, during which years its impact on other sub-sectors increased abruptly. This phenomenon may be attributed to the occurrence of financial crises, which led to a surge in precious metal prices. The Beverages sub-sector has maintained a low net spillover index, with a peak around 2008, indicating a high degree of influence from other sub-sectors. Since 2014, its net spillover index has fluctuated around zero. The net spillover index of the Oils & Meals sub-sector underwent a positive-negative reversal for a period of 1–2 years around 1990; during all other periods, it has remained consistently positive with relatively large values. In other words, the Oils & Meals sub-sector has been continuously transmitting risks to the broader commodity market, with a relatively significant degree of impact. Prior to 2010, the net spillover index of the Fertilizers sub-sector remained at a low level, fluctuating around zero. After 2010, it

suddenly dropped to a negative peak and then declined slightly, followed by a sustained upward trend in negative values to the present day. This implies that the impact of other sub-sectors on the Fertilizers sub-sector increased abruptly and then decreased sharply in 2010; since then, its degree of correlation with other sub-sectors has gradually increased, and it has mainly been subject to risk spillovers from other markets. The net spillover index of the Other Food sub-sector has remained consistently negative, meaning that this sub-sector only receives risk spillovers from other markets and does not transmit any risks to them.

4.2.4. Spillover Network Analysis

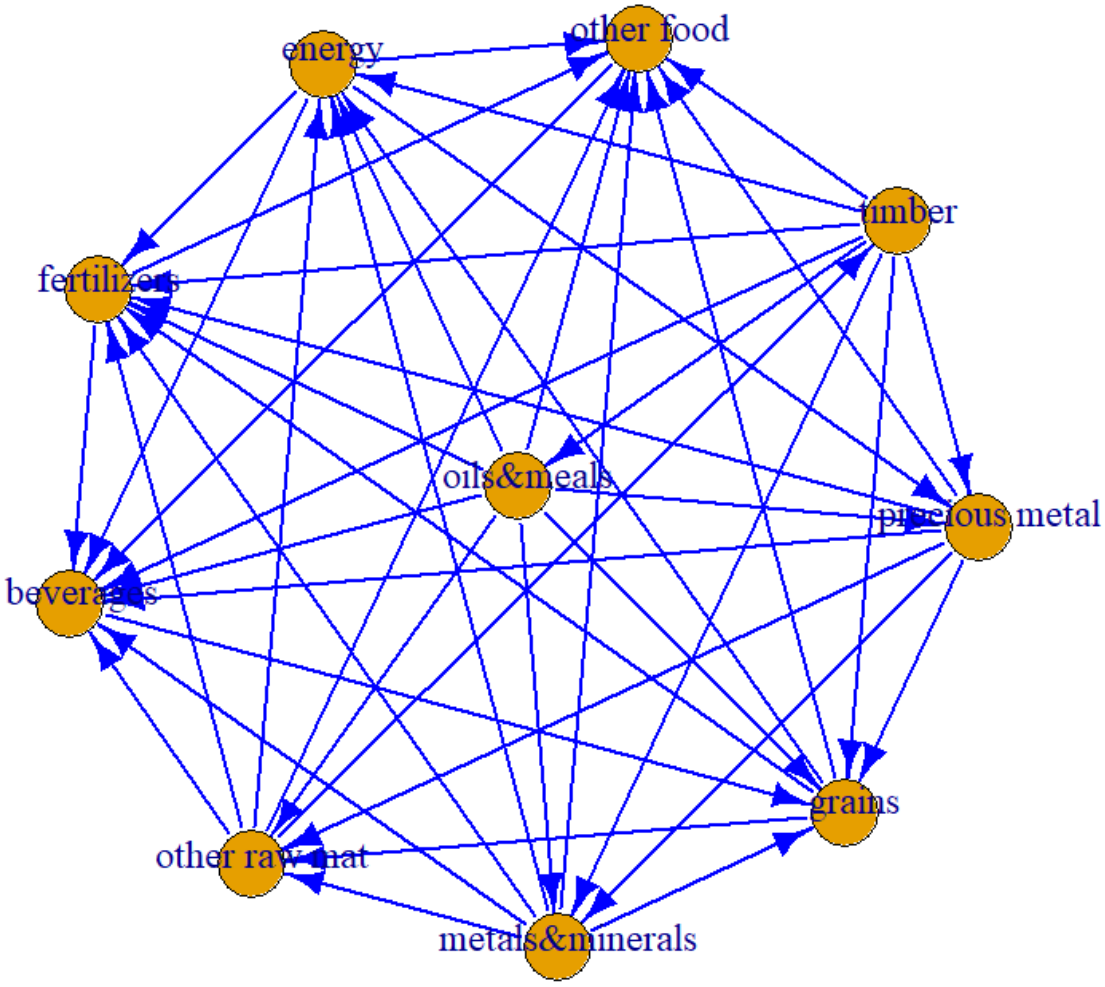

Figure 4.3 Spillover Network Among Commodity Markets

Figure 4.3 plots the spillover network diagram among the 10 sub-sectors of the commodity market, where the direction of the arrows indicates the direction of spillovers. As can be seen from Figure 2.3, Oils & Meals is the primary risk transmitter in the commodity market: it only receives spillovers from Timber and acts as a spillover contributor to all other sub-sectors. In contrast, Beverages, Timber, and Other Food are the main spillover receivers in the commodity market. Each of these sub-sectors only exerts spillover effects on one single market, while simultaneously receiving spillover effects from the other eight sub-sectors.

4.3. The Impact of Uncertainty Indices on Spillover Indices

An extended Autoregressive (AR) model is constructed to separately investigate the impacts of the eight uncertainty index variables on the total spillover index of the commodity market. The regression results are presented in the following table.

Table 4.3 Regression Results

	parameter estimate	P Value
GPR	0.0058499	0.18702
GEPU	0.00020541	0.99046
USEPU	0.019052	0.2866
EUI	0.1851	0.18978
CPU	8.61E-05	0.97714
OVX	-0.015571	0.61572
OPU	0.00054849	0.66997
VIX	0.60088	0.00011362

As shown in Table 4.3, when the eight uncertainty index variables are individually incorporated into the model, only the estimated statistic of the VIX variable is significant at the 5% significance level, with a parameter estimate of 0.60088. In other words, when the Volatility Index (VIX) of the Chicago Board Options Exchange rises, the spillover effects among commodity markets also increase. This phenomenon may be attributed to the fact that a higher VIX may trigger speculative sentiment in the market. Some investors may take advantage of market volatility to conduct short-term trading or speculative operations, which could lead to an increase in trading volume and more drastic price fluctuations in the commodity market.

4.4. Robustness Checks

This paper divides the sample period into two sub-periods, and separately examines whether the impact of VIX on the spillover relationships among commodity markets still exists in each of the two sub-periods. The results are presented in the following table:

Table 4.4 Robustness Checks

	parameter estimate	P Valie
1990.01-2006.12	-0.025707	0.24114
2007.01-2023.12	0.10644	1.942e-06

As can be seen from the robustness check results in Table 4.4, the positive impact of VIX on the spillover relationships among commodity markets still exists and remains significant during the period from January 2007 to December 2023. In contrast, during the period from January 1990 to December 2006, the impact of VIX on the spillover relationships among commodity markets is negative and insignificant. This may be attributed to the changes in the macro-financial environment between 2007 and 2023. For example, the degree of financialization in the global financial markets may have further deepened, which has led to a positive impact of VIX on the spillover relationships among commodity markets.

5. Conclusions

To investigate the spillover relationships among commodity markets and the impacts of uncertainty index variables on these relationships, this paper divides the overall commodity market into 10 sub-sectors, selects 8 uncertainty index variables, and employs the Diebold-Yilmaz (DY) spillover approach and autoregressive (AR) regression models to address this research issue.

The empirical results indicate that: first, the mean spillover index among commodity markets exhibits distinct time-varying characteristics, with a fluctuation range of 20% to 50% and three clear stages of temporal evolution; second, the directional mean spillovers from individual sub-sectors to the overall commodity market are asymmetric and time-varying; third, the mean spillovers between any two sub-sectors are bidirectional and dynamic, while the impacts exerted by a single sub-sector on other markets are asymmetric.

Based on the pairwise spillover and net spillover indices, Oils & Meals emerges as the primary risk transmitter in the commodity market, featuring the largest net spillover index value and thus making the most significant contribution to market connectedness.

Among the 8 uncertainty index variables, only the positive impact of VIX on the commodity market is statistically significant. Robustness checks are conducted by splitting the full sample into two sub-periods, and the results show that the significant positive impact of VIX is only maintained in the sub-period from January 2007 to December 2023. This phenomenon may be attributed to changes in the macro-financial environment. For instance, the degree of financialization in global financial markets may have further deepened, which has led to a positive impact of VIX on the spillover relationships among commodity markets.

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