Quantitative Finance and Economics

Research article

Geopolitical risk transmission dynamics to commodity, stock, and energy markets

Mohammad Ashraful Ferdous Chowdhury[1], M Kabir Hassan[2], Mohammad Abdullah[3,*] and Md Mofazzal Hossain[1]

[1] Department of Business Administration, Shahjalal University of Science & Technology, Sylhet, Bangladesh

[2] Department of Economics and Finance, College of Business Administration, University of New Orleans, New Orleans, USA

[3] Southampton Malaysia Business School, University of Southampton, Johor, Malaysia

* **Correspondence:** Email: M.Abdullah@soton.ac.uk.

Supplementary

Appendix A

Table A.1. Summary of the variables.

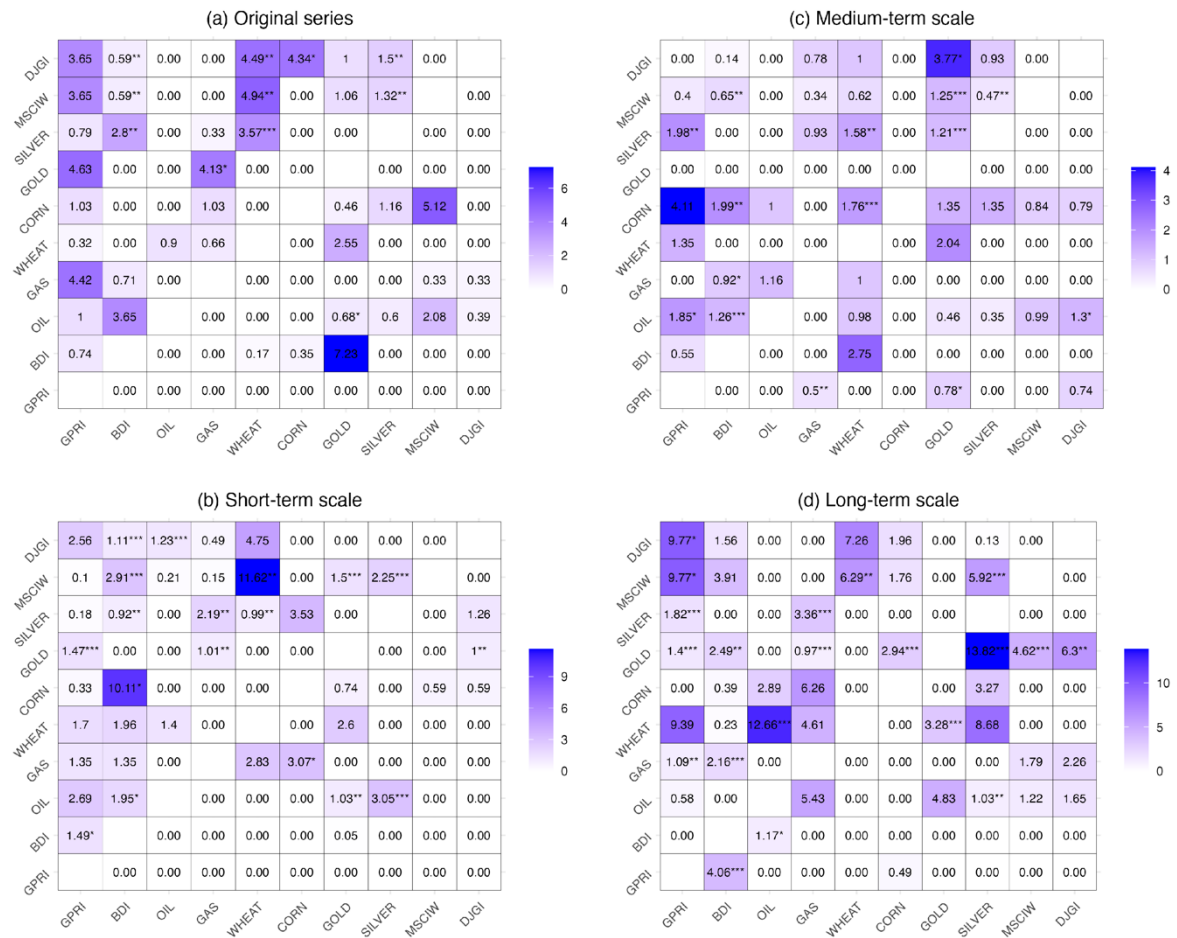| Variable	Description	Variable Category	Data Source
GPRI	Geopolitical risk index	GPR	Caldara et al. (2022)
BDI	Baltic Dry Index (BDI) - Price Index	Economic Activity	Datastream
OIL	S&P GSCI Crude Oil Spot - Price Index	Energy	Datastream
GAS	S&P GSCI Natural Gas Spot - Price Index	Energy	Datastream
WHEAT	S&P GSCI All Wheat Spot - Price Index	AgriculturalCommodity	Datastream
CORN	S&P GSCI Corn Spot - Price Index	Agricultural Commodity	Datastream
GOLD	S&P GSCI Gold Spot - Price Index	Previous Metal Commodity	Datastream
SILVER	S&P GSCI Silver Spot - Price Index	Previous Metal Commodity	Datastream
MSCIW	MSCI World - Price Index	Stock Market	Datastream
DJGI	Dow Jones Global - Price Index	Stock Market	Datastream

Supplementary
Figures S.1 to S.9

Online Supplementary Material

(a) Original series

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	0.00	4.21*	0.00	2.59	0.00	0.00	1.23	0.00	
MSCIW	0.00	0.00	4.21	0.00	7.85***	0.00	2.92**	7.79**		0.00
SILVER	0.00	8.07	0.00	0.35	0.00	0.55	0.00		0.00	0.00
GOLD	1.21	0.00	0.00	0.00	0.00	0.83**		0.00	0.00	3.33**
CORN	4.53	0.00	0.00	0.00	0.00		0.00	0.00	1.06	0.82
WHEAT	0.00	9.57	0.00	0.83		0.00	2.88	2.37***	0.00	0.00
GAS	2.04***	2.06	0.00		0.00	0.76	0.00	0.00	1.9**	3.67**
OIL	3.96	0.00		3.98	0.76	6.38***	0.00	0.00	0.00	0.00
BDI	0.00		0.62	0.00	0.00	0.5	3.95	0.00	6.06	0.84
GPRI		0.94	0.00	0.00	4.46	0.00	0.00	0.71	0.85	0.67

(c) Medium-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.13	0.34	2.06***	3.74	0.00	0.00	0.71***	6.24***	0.00	
MSCIW	0.85	2.13*	1.45***	0.63	0.00	0.00	3.2***	10.7***		0.00
SILVER	1.26	0.83	0.00	5.33***	1.8*	1.88*	0.00		0.00	0.00
GOLD	0.6	2.45	0.00	0.94**	1.35	1.13		0.00	0.00	0.00
CORN	0.00	0.00	0.00	0.00	0.00		0.00	0.00	1.18*	3.07**
WHEAT	0.16	0.99	9.38**	0.34		2.47***	0.00	0.00	1	9.38**
GAS	0.00	0.00	0.00		0.00	1	0.00	0.00	0.00	0.00
OIL	1	0.74		1.57***	0.00	2.96	1.45	2.04**	0.00	0.00
BDI	0.25		0.00	2.73	0.00	2.21	0.00	0.00	0.00	0.00
GPRI		0.00	0.00	1.27**	0.00	0.15	0.00	0.00	0.00	0.00

(b) Short-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	0.82	0.00	0.00	0.00	0.00	0.00	1.13	0.00	
MSCIW	0.00	0.82	0.00	1	0.00	0.00	0.37	0.22		0.00
SILVER	0.22	0.43	1.35	0.00	2.31**	0.13	0.00		0.00	0.00
GOLD	1.35	0.00	0.00	3.76**	0.00	0.51		0.00	0.00	0.61
CORN	0.00	0.59	0.00	0.00	0.00		0.00	0.00	0.54	0.47
WHEAT	0.00	1.44	0.00	9.19		0.00	0.14	0.00	0.9	0.17
GAS	0.36	3.71	0.00		0.00	0.00	0.00	0.79	0.00	2.04**
OIL	1	1		1	1.32	2.36	0.84	0.00	3.52	1.16
BDI	0.00		0.00	0.00	0.00	0.00	0.91*	0.00	0.00	0.00
GPRI		1.28**	0.00	0.00	0.92	1.71	0.00	0.00	0.41	0.96

(d) Long-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	1.02	0.00	4.12	0.00	4.99	5.34***	0.00	0.00	
MSCIW	0.00	0.83	0.00	0.83	0.00	4.57	0.96	0.00		0.00
SILVER	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.62*	3.16***
GOLD	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
CORN	1	0.00	0.00	0.27	4.67***		1	0.84	0.00	0.00
WHEAT	0.00	0.00	1	1.31		0.00	0.79	5.55*	1.12	0.84
GAS	0.00	0.22	0.00		0.00	0.00	2.46*	2.28	0.00	0.00
OIL	3.45	4.67		9.49**	0.00	5.89	3.34	0.00	3.85**	3.85**
BDI	0.00		0.00	0.00	0.31	0.21	4.54*	3.41**	0.00	0.00
GPRI		11.07**	0.00	5.1***	2.13*	0.00	4.72	1	0.00	0.00

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Figure S.1. Asian and Russian Financial Crisis (1998-08-17 to 1998-11-17).
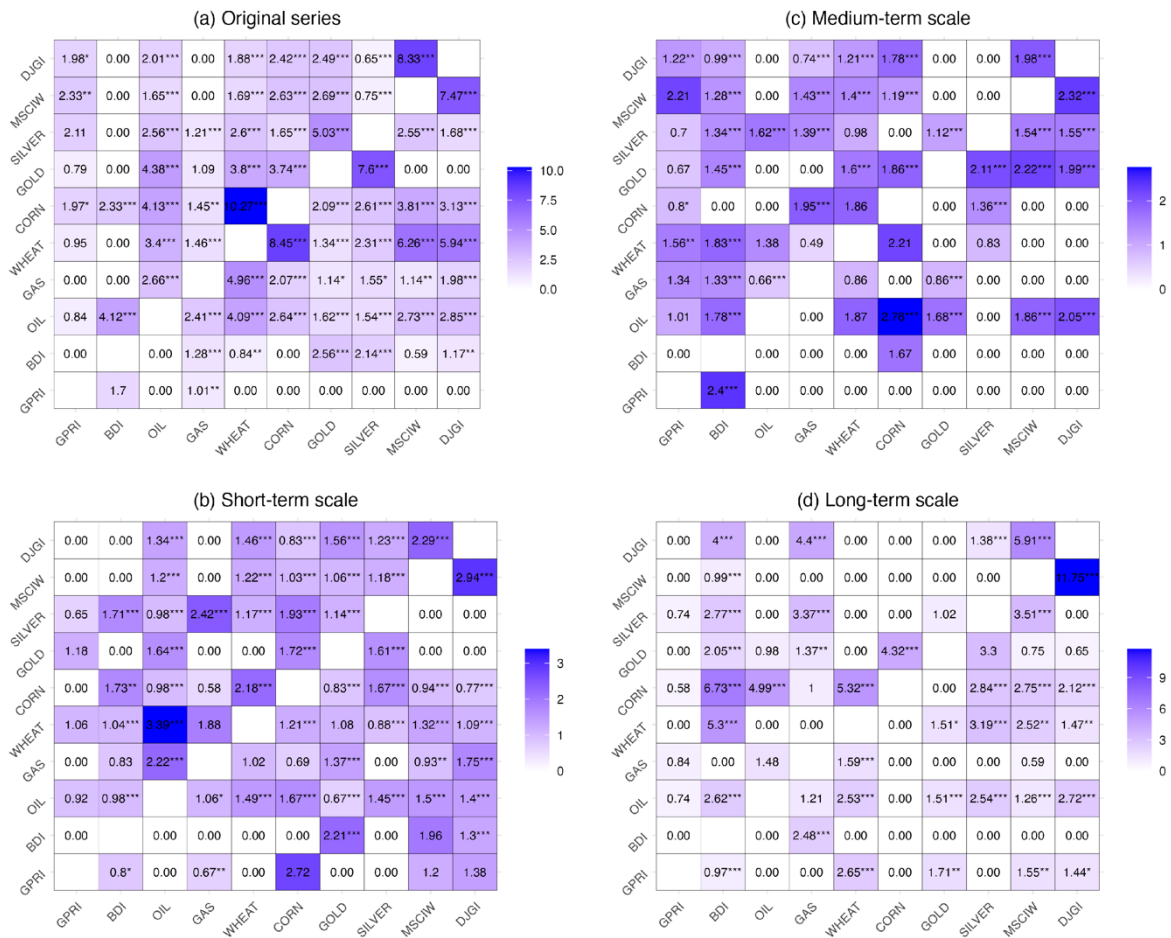
(a) Original series

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	3.65	0.59**	0.00	0.00	4.49**	4.34*	1	1.5**	0.00	
MSCIW	3.65	0.59**	0.00	0.00	4.94**	0.00	1.06	1.32**		0.00
SILVER	0.79	2.8**	0.00	0.33	3.57***	0.00	0.00		0.00	0.00
GOLD	4.63	0.00	0.00	4.13*	0.00	0.00		0.00	0.00	0.00
CORN	1.03	0.00	0.00	1.03	0.00		0.46	1.16	5.12	0.00
WHEAT	0.32	0.00	0.9	0.66		0.00	2.55	0.00	0.00	0.00
GAS	4.42	0.71	0.00		0.00	0.00	0.00	0.00	0.33	0.33
OIL	1	3.65		0.00	0.00	0.00	0.68*	0.6	2.08	0.39
BDI	0.74		0.00	0.00	0.17	0.35	7.23	0.00	0.00	0.00
GPRI		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(c) Medium-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	0.14	0.00	0.78	1	0.00	3.77*	0.93	0.00	
MSCIW	0.4	0.65**	0.00	0.34	0.62	0.00	1.25***	0.47**		0.00
SILVER	1.98**	0.00	0.00	0.93	1.58**	0.00	1.21***		0.00	0.00
GOLD	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
CORN	4.11	1.99**	1	0.00	1.76***		1.35	1.35	0.84	0.79
WHEAT	1.35	0.00	0.00	0.00		0.00	2.04	0.00	0.00	0.00
GAS	0.00	0.92*	1.16		1	0.00	0.00	0.00	0.00	0.00
OIL	1.85*	1.26***		0.00	0.98	0.00	0.46	0.35	0.99	1.3*
BDI	0.55		0.00	0.00	2.75	0.00	0.00	0.00	0.00	0.00
GPRI		0.00	0.00	0.5**	0.00	0.00	0.78*	0.00	0.00	0.74

(b) Short-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	2.56	1.11***	1.23***	0.49	4.75	0.00	0.00	0.00	0.00	
MSCIW	0.1	2.91***	0.21	0.15	11.62**	0.00	1.5***	2.25***		0.00
SILVER	0.18	0.92**	0.00	2.19**	0.99**	3.53	0.00		0.00	1.26
GOLD	1.47***	0.00	0.00	1.01**	0.00	0.00		0.00	0.00	1**
CORN	0.33	10.11*	0.00	0.00	0.00		0.74	0.00	0.59	0.59
WHEAT	1.7	1.96	1.4	0.00		0.00	2.6	0.00	0.00	0.00
GAS	1.35	1.35	0.00		2.83	3.07*	0.00	0.00	0.00	0.00
OIL	2.69	1.95*		0.00	0.00	0.00	1.03**	3.05***	0.00	0.00
BDI	1.49*		0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
GPRI		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(d) Long-term scale

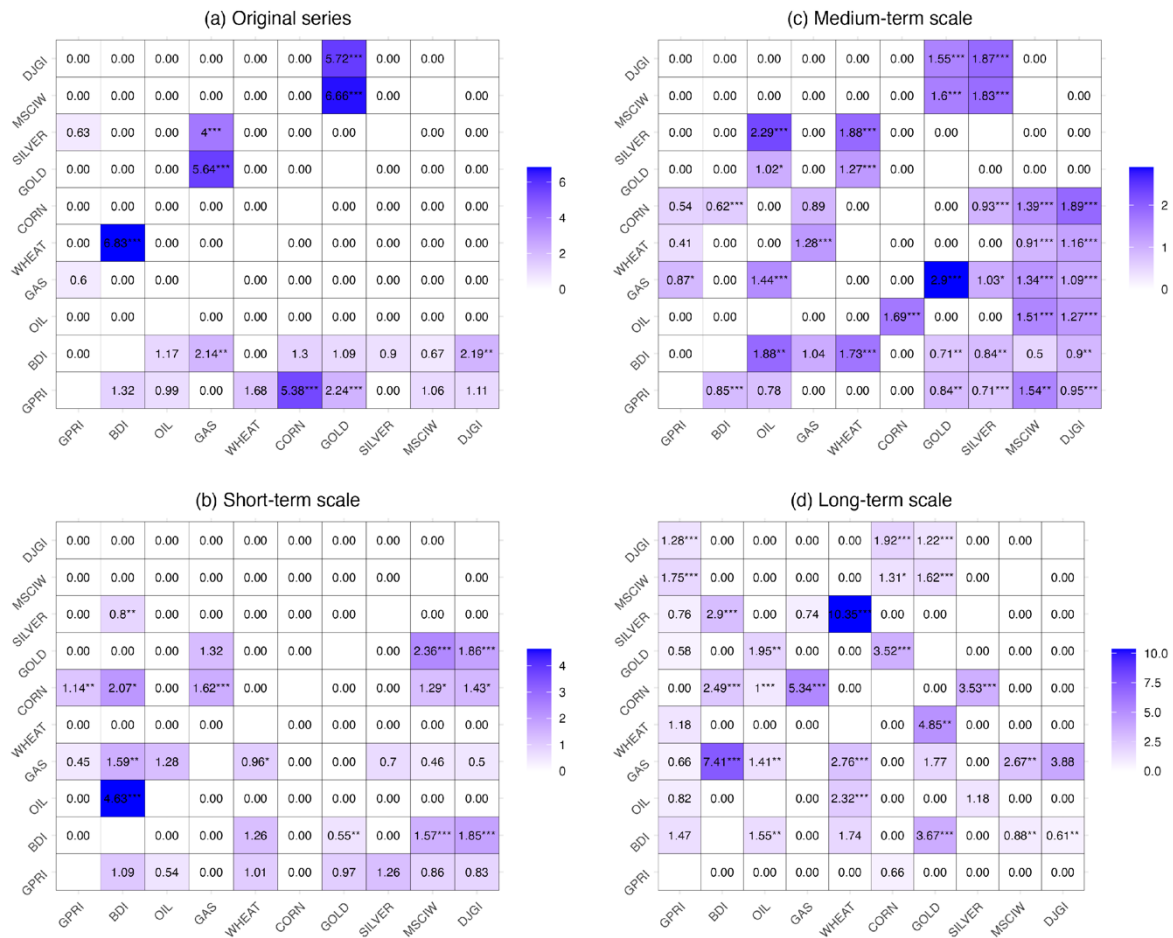|	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	9.77*	1.56	0.00	0.00	7.26	1.96	0.00	0.13	0.00	
MSCIW	9.77*	3.91	0.00	0.00	6.29**	1.76	0.00	5.92***		0.00
SILVER	1.82***	0.00	0.00	3.36***	0.00	0.00	0.00		0.00	0.00
GOLD	1.4***	2.49**	0.00	0.97***	0.00	2.94***		3.82**	4.62***	6.3*
CORN	0.00	0.39	2.89	6.26	0.00		0.00	3.27	0.00	0.00
WHEAT	9.39	0.23	12.66***	4.61		0.00	3.28**	8.68	0.00	0.00
GAS	1.09**	2.16***	0.00		0.00	0.00	0.00	0.00	1.79	2.26
OIL	0.58	0.00		5.43	0.00	0.00	4.83	1.03**	1.22	1.65
BDI	0.00		1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GPRI		4.06***	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. $***$, $**$, and $*$ indicate significance at the 1%, 5%, and 10% level, respectively.

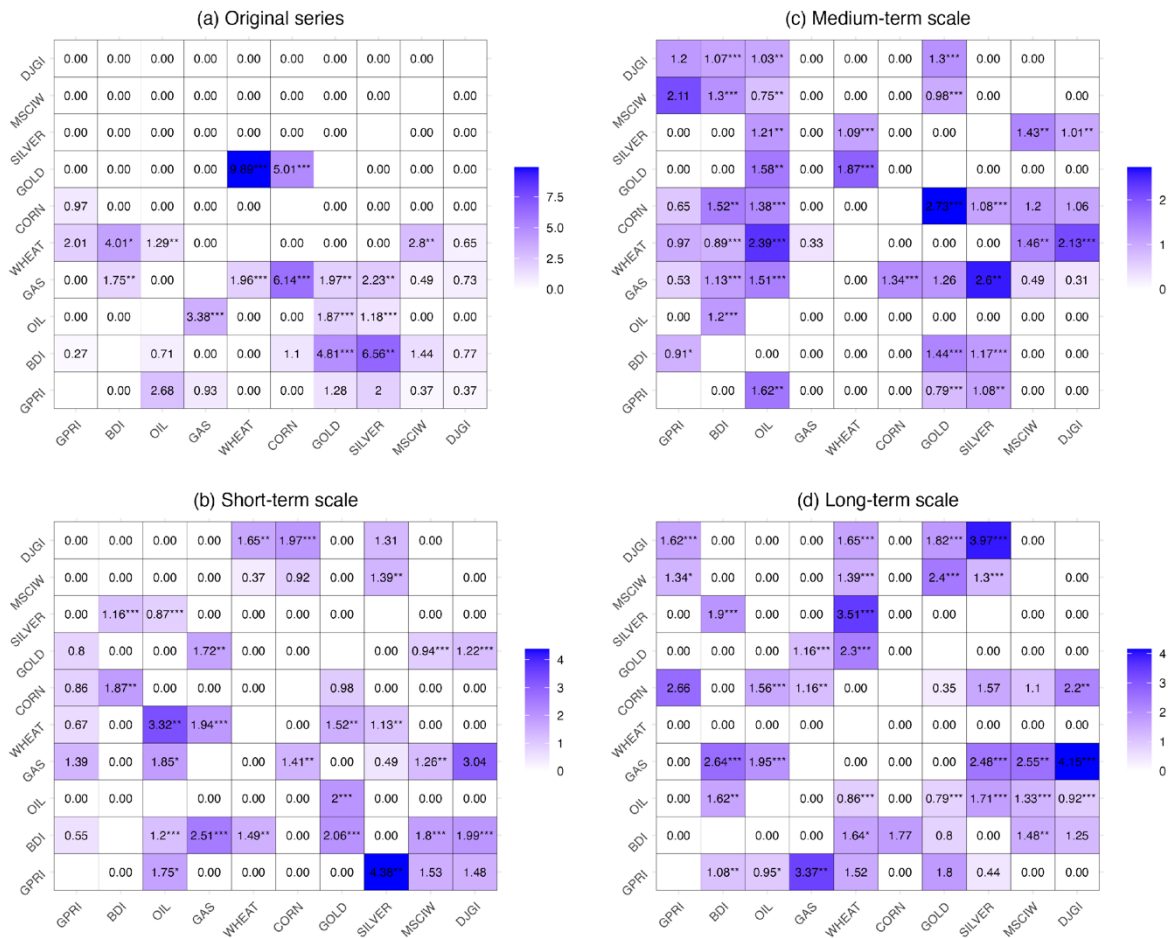**Figure S.2.** 9/11 (2001-09-11 to 2001-12-11).

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively.

Figure S.3. Gulf War II (2003-01-01 to 2011-12-15).

(a) Original series

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	1.98*	0.00	2.01***	0.00	1.88***	2.42***	2.49***	0.65***	8.33***	
MSCIW	2.33**	0.00	1.65***	0.00	1.69***	2.63***	2.69***	0.75***		7.47***
SILVER	2.11	0.00	2.56***	1.21***	2.6***	1.65***	5.03***		2.55***	1.68***
GOLD	0.79	0.00	4.38***	1.09	3.8***	3.74***		7.6***	0.00	0.00
CORN	1.97*	2.33***	4.13***	1.45**	0.27***		2.09***	2.61***	3.81***	3.13***
WHEAT	0.95	0.00	3.4***	1.46***		8.45***	1.34***	2.31***	6.26***	5.94***
GAS	0.00	0.00	2.66***		4.96***	2.07***	1.14*	1.55*	1.14**	1.98***
OIL	0.84	4.12***		2.41***	4.09***	2.64***	1.62***	1.54***	2.73***	2.85***
BDI	0.00		0.00	1.28***	0.84**	0.00	2.56***	2.14***	0.59	1.17**
GPRI		1.7	0.00	1.01**	0.00	0.00	0.00	0.00	0.00	0.00

(c) Medium-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	1.22**	0.99***	0.00	0.74***	1.21***	1.78***	0.00	0.00	1.98***	
MSCIW	2.21	1.28***	0.00	1.43***	1.4***	1.19***	0.00	0.00		2.32***
SILVER	0.7	1.34***	1.62***	1.39***	0.98	0.00	1.12***		1.54***	1.55***
GOLD	0.67	1.45***	0.00	0.00	1.6***	1.86***		2.11***	2.22***	1.99***
CORN	0.8*	0.00	0.00	1.95***	1.86		0.00	1.36***	0.00	0.00
WHEAT	1.56**	1.83***	1.38	0.49		2.21	0.00	0.83	0.00	0.00
GAS	1.34	1.33***	0.66***		0.86	0.00	0.86***	0.00	0.00	0.00
OIL	1.01	1.78***		0.00	1.87	2.76***	1.68***	0.00	1.86***	2.05***
BDI	0.00		0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.00
GPRI		2.4***	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(b) Short-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	0.00	1.34***	0.00	1.46***	0.83***	1.56***	1.23***	2.29***	
MSCIW	0.00	0.00	1.2***	0.00	1.22***	1.03***	1.06***	1.18***		2.94***
SILVER	0.65	1.71***	0.98***	2.42***	1.17***	1.93***	1.14***		0.00	0.00
GOLD	1.18	0.00	1.64***	0.00	0.00	1.72***		1.61***	0.00	0.00
CORN	0.00	1.73**	0.98***	0.58	2.18***		0.83***	1.67***	0.94***	0.77***
WHEAT	1.06	1.04***	3.39***	1.88		1.21***	1.08	0.88***	1.32***	1.09***
GAS	0.00	0.83	2.22***		1.02	0.69	1.37***	0.00	0.93***	1.75***
OIL	0.92	0.98***		1.06*	1.49***	1.67***	0.67***	1.45***	1.5***	1.4***
BDI	0.00		0.00	0.00	0.00	0.00	2.21***	0.00	1.96	1.3***
GPRI		0.8*	0.00	0.67**	0.00	2.72	0.00	0.00	1.2	1.38

(d) Long-term scale

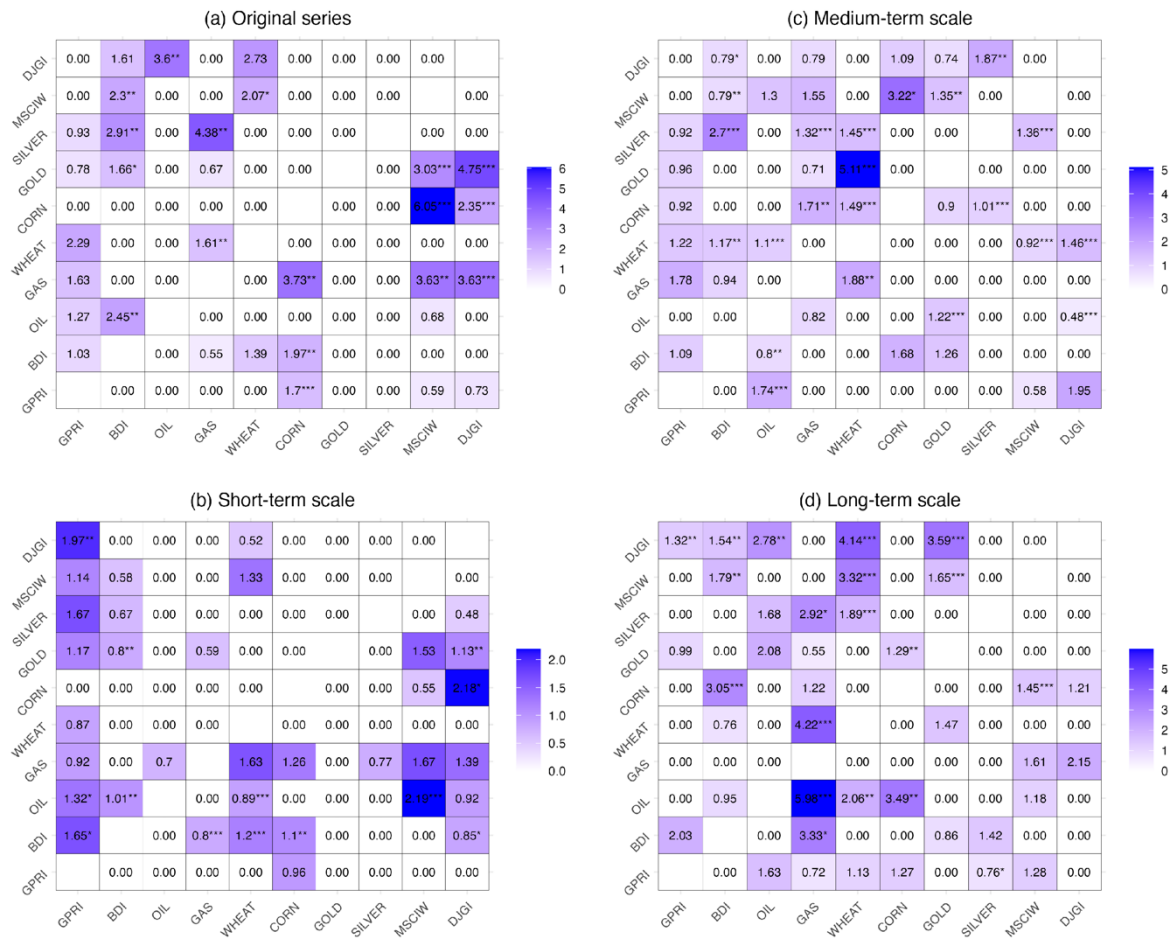|	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	4***	0.00	4.4***	0.00	0.00	0.00	1.38***	5.91***	
MSCIW	0.00	0.99***	0.00	0.00	0.00	0.00	0.00	0.00		1.75**
SILVER	0.74	2.77***	0.00	3.37***	0.00	0.00	1.02		3.51***	0.00
GOLD	0.00	2.05***	0.98	1.37**	0.00	4.32***		3.3	0.75	0.65
CORN	0.58	6.73***	4.99***	1	5.32***		0.00	2.84***	2.75***	2.12***
WHEAT	0.00	5.3***	0.00	0.00		0.00	1.51*	3.19***	2.52**	1.47**
GAS	0.84	0.00	1.48		1.59***	0.00	0.00	0.00	0.59	0.00
OIL	0.74	2.62***		1.21	2.53***	0.00	1.51***	2.54***	1.26***	2.72***
BDI	0.00		0.00	2.48***	0.00	0.00	0.00	0.00	0.00	0.00
GPRI		0.97***	0.00	0.00	2.65***	0.00	1.71**	0.00	1.55**	1.44*

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively.

Figure S.4. Global Financial Crisis (2007-01-01 to 2008-12-20).

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively.
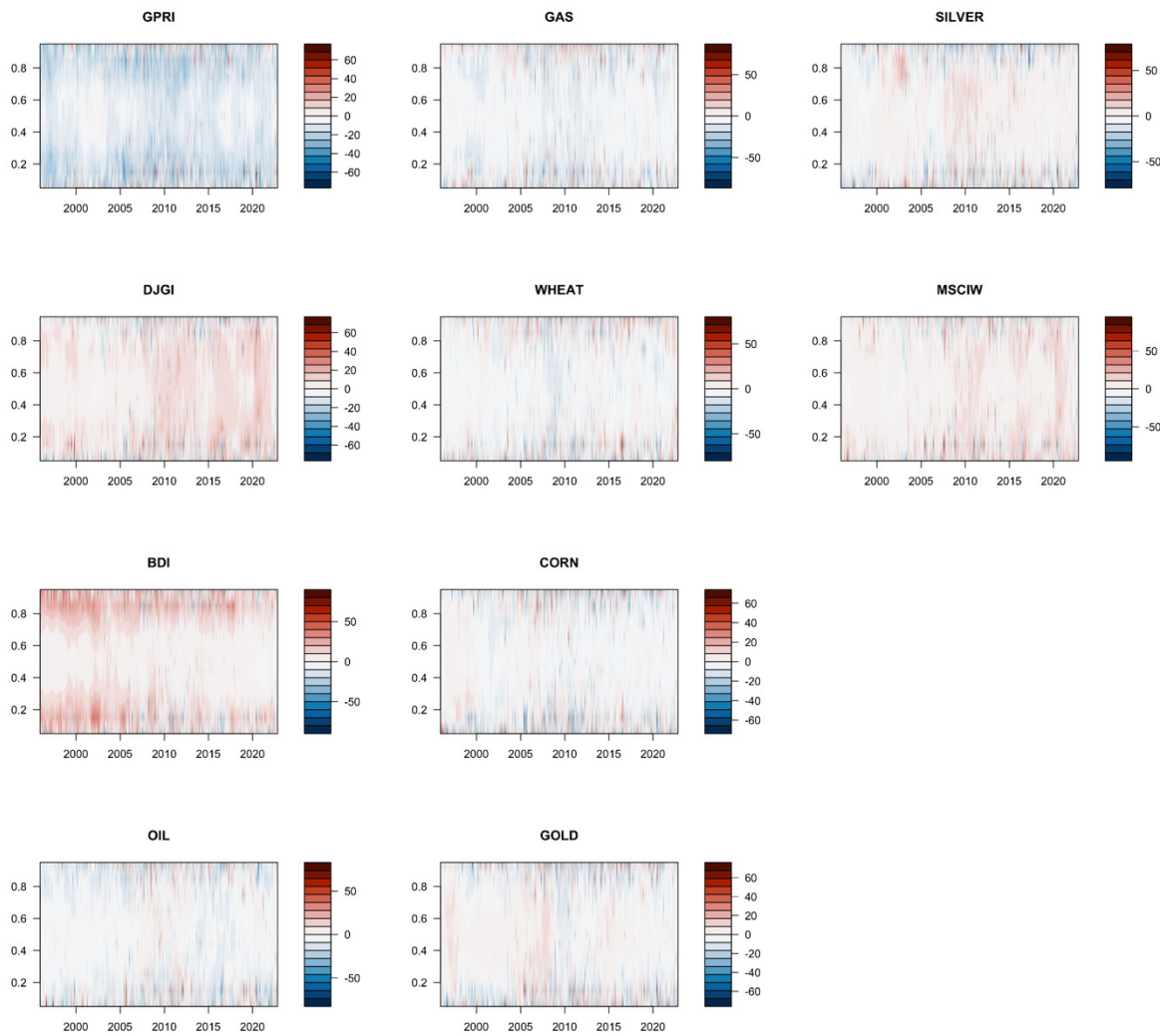
Figure S.5. European debt crisis (2009-01-01 to 2010-12-20).

(a) Original series

(b) Short-term scale

(c) Medium-term scale

(d) Long-term scale

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively.

Figure S.6. COVID-19 (2020-01-01 to 2021-12-20).

(a) Original series

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	1.61	3.6**	0.00	2.73	0.00	0.00	0.00	0.00	
MSCIW	0.00	2.3**	0.00	0.00	2.07*	0.00	0.00	0.00		0.00
SILVER	0.93	2.91**	0.00	4.38**	0.00	0.00	0.00		0.00	0.00
GOLD	0.78	1.66*	0.00	0.67	0.00	0.00		0.00	3.03***	4.75***
CORN	0.00	0.00	0.00	0.00	0.00		0.00	0.00	6.05***	2.35***
WHEAT	2.29	0.00	0.00	1.61**		0.00	0.00	0.00	0.00	0.00
GAS	1.63	0.00	0.00		0.00	3.73**	0.00	0.00	3.63**	3.63***
OIL	1.27	2.45**		0.00	0.00	0.00		0.00	0.68	0.00
BDI	1.03		0.00	0.55	1.39	1.97**	0.00	0.00	0.00	0.00
GPRI		0.00	0.00	0.00	0.00	1.7***	0.00	0.00	0.59	0.73

(c) Medium-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	0.00	0.79*	0.00	0.79	0.00	1.09	0.74	1.87**	0.00	
MSCIW	0.00	0.79*	1.3	1.55	0.00	3.22*	1.35**	0.00		0.00
SILVER	0.92	2.7***	0.00	1.32***	1.45***	0.00	0.00		1.36***	0.00
GOLD	0.96	0.00	0.00	0.71	3.11***	0.00		0.00	0.00	0.00
CORN	0.92	0.00	0.00	1.71**	1.49**		0.9	1.01***	0.00	0.00
WHEAT	1.22	1.17**	1.1***	0.00		0.00	0.00	0.00	0.92***	1.46***
GAS	1.78	0.94	0.00		1.88**	0.00	0.00	0.00	0.00	0.00
OIL	0.00	0.00		0.82	0.00	0.00	1.22***	0.00	0.00	0.48***
BDI	1.09		0.8**	0.00	0.00	1.68	1.26	0.00	0.00	0.00
GPRI		0.00	1.74**	0.00	0.00	0.00	0.00	0.00	0.58	1.95

(b) Short-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	1.97**	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	
MSCIW	1.14	0.58	0.00	0.00	1.33	0.00	0.00	0.00		0.00
SILVER	1.67	0.67	0.00	0.00	0.00	0.00	0.00		0.00	0.48
GOLD	1.17	0.8**	0.00	0.59	0.00	0.00		0.00	1.53	1.13**
CORN	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.55	2.18*
WHEAT	0.87	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
GAS	0.92	0.00	0.7		1.63	1.26	0.00	0.77	1.67	1.39
OIL	1.32*	1.01**		0.00	0.89***	0.00	0.00	0.00	2.19***	0.92
BDI	1.65*		0.00	0.8***	1.2**	1.1**	0.00	0.00	0.00	0.85*
GPRI		0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00

(d) Long-term scale

	GPRI	BDI	OIL	GAS	WHEAT	CORN	GOLD	SILVER	MSCIW	DJGI
DJGI	1.32**	1.54**	2.78**	0.00	4.14***	0.00	3.59***	0.00	0.00	
MSCIW	0.00	1.79**	0.00	0.00	3.32**	0.00	1.65***	0.00		0.00
SILVER	0.00	0.00	1.68	2.92*	1.89***	0.00	0.00		0.00	0.00
GOLD	0.99	0.00	2.08	0.55	0.00	1.29**		0.00	0.00	0.00
CORN	0.00	3.05***	0.00	1.22	0.00		0.00	0.00	1.45***	1.21
WHEAT	0.00	0.76	0.00	4.22***		0.00	1.47	0.00	0.00	0.00
GAS	0.00	0.00	0.00		0.00	0.00	0.00	0.00	1.61	2.15
OIL	0.00	0.95		5.88***	2.06**	3.49**	0.00	0.00	1.18	0.00
BDI	2.03		0.00	3.33*	0.00	0.00	0.86	1.42	0.00	0.00
GPRI		0.00	1.63	0.72	1.13	1.27	0.00	0.76*	1.28	0.00

Note: Figure presents the Transfer-Entropy ratio of a,b,c,d scales. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively.
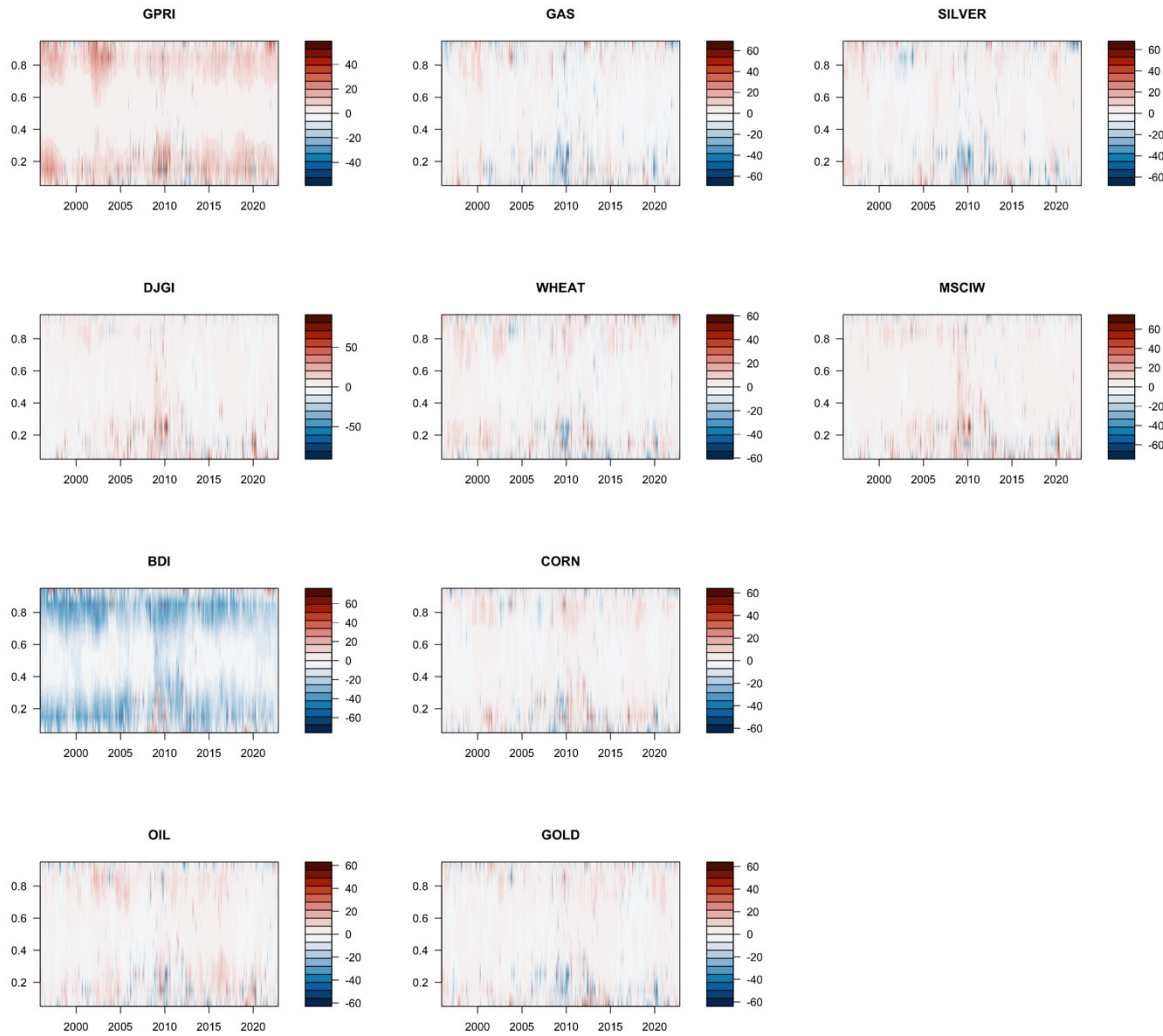
Figure S.7. Russia-Ukraine War (2022-01-01 to 2022-10-31).

…

Notes: Results are based on a GFEVD with 100 steps in advance and a 504-days rolling-window QVAR model with lag length of order 6 (AIC).

Figure S.8. Net total directional connectedness across quantiles (Short-term).

Notes: Results are based on a GFEVD with 12 steps in advance and a 60-months rolling-window QVAR model with lag length of order 2 (AIC).

Figure S.9. Net total directional connectedness across quantiles (Long-term).