Temporal dynamics of volatility spillover:

The case of energy markets

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Abstract

- Examines the volatility spillover between the five energy markets using futures data from July 2001 to June 2016.
- Investigate how the change in price and return dynamics of energy commodities affects each other.
- Spillover is relatively stable over time.
- Increases significantly during the period of financial and economic turmoil.
- Crude oil and Heating oil significantly influence the volatility in other energy commodities.
- Finally, short-term events tends to have major influence on spillover dynamics.

Introduction

- Transmission of volatility or volatility spillover has been a debated topic within both financial and commodity literature.
- Studies in volatility spillover receives considerably less attention.
- Understanding the dynamics of time-varying volatility transmission is crucial for:
  - investment allocation
  - asset valuation
  - risk management and policymaking
- We examine spillover between the five energy commodities: crude oil, natural gas, coal, gasoline, and heating oil.
- Phenomenon of volatility spillover is time-varying and recent decline in oil price necessitate the evaluation of volatility spillover between the energy commodities.

Research Question

- Describe the prevalence and inherit characteristics of bidirectional static and temporal volatility spillover between the energy nexus.
- Providing an overview how the recent decline in crude oil price has changed the spillover dynamics between the energy commodities.
- Offer policy recommendation aimed at augmenting decision-making for private and institutional investors.
- Empirically investigate the historical claim of volatility transmission from crude oil.
- As pointed by Asche et al. (2012), it is important to understand the development of relationship between natural gas and coal, because natural gas is often considered a substitute to coal.

Literature review

Study	Assets/Markets	Data	Method	Results
Malik and Hammoudeh (2007)	U.S. equity market, crude oil, and Gulf markets	1994–2001 (Daily)	MGARCH	Significant
Baffes (2007)	Crude oil and 35 other commodities	1960–2005 (Annual)	OLS	Significant
Serra (2011)	Crude oil, ethanol, and sugar prices in Brazil	2000–2009 (Weekly)	GARCH	Significant
Kaltalioglu et al. (2011)	Oil price, agricultural commodities and food items	1980–2008 (Monthly)	VAR	Insignificant
Lin and Li (2015)	Crude oil and natural gas markets	1992–2012 (Monthly)	VECM MGARCH	Significant
Diaz et al. (2016)	Crude oil and stock returns in G7 countries	1970–2014 (Monthly)	VAR	Insignificant
Liu et al. (2017)	Crude oil, MICEX, and S&P 500	2003–2014 (Daily)	GARCH–BEKK	Insignificant
Kang et al. (2017)	Crude oil, gold, silver, corn, wheat, and rice	2002–2012 (Weekly)	DY (2009, 2012)	Insignificant

Methodology I

- Following Diebold and Yilmaz (2012, 2009), we can estimate the volatility spillover as:

$$x_t = \sum_{i=1}^{p} \phi_i x_{t-i} + \varepsilon_t \quad \text{where } \varepsilon \sim (0, \sum) \tag{1}$$

Equation 2 provides H-step-ahead forecast error variance decomposition:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \sum A_h' e_j)} \tag{2}$$

Methodology II

Estimate of the directional volatility spillovers are as follows:

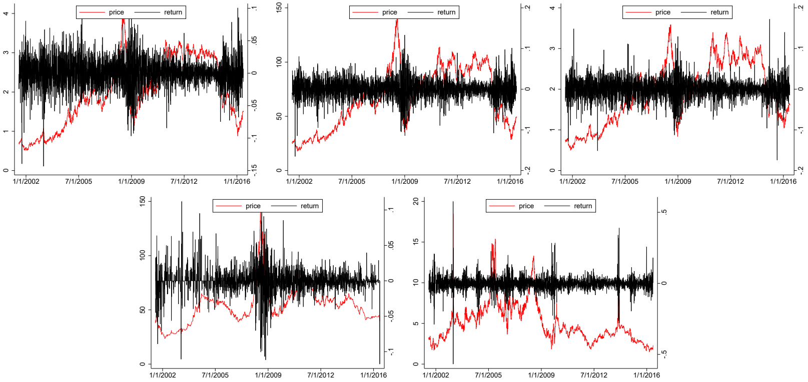
$$S_{i\cdot}^{g}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \cdot 100, \qquad S_{\cdot i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} \cdot 100. \tag{3}$$

Equation 4 provides net pairwise spillovers between the assets i and j:

$$S_{ij}^{g}(H) = \left(\frac{\tilde{\theta}_{ij}^{g}(H)}{\sum_{k=1}^{N} \tilde{\theta}_{ik}^{g}(H)} - \frac{\tilde{\theta}_{ji}^{g}(H)}{\sum_{k=1}^{N} \tilde{\theta}_{jk}^{g}(H)} \right) \cdot 100 \tag{4}$$

Data and descriptives

- Dataset of futures prices of five commodities spanning 07.12.2001 to 03.06.2016.
- Data chosen from Commodity Research Bureau (CRB).
- Heating oil, crude oil, gasoline, coal, and natural gas.



Descriptive statistics

Table: **Descriptive statistics of daily log returns**

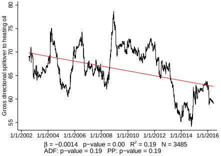
Commodity	Mean	Std dev	Skew	Kurtosis	Min	Max	JB	AC
Heating oil	0.05	0.34	-0.12	5.67	-0.14	0.10	0.00	-0.03 (0.03)
Crude oil	0.04	0.36	-0.13	6.25	-0.17	0.13	0.00	-0.05 (0.00)
Gasoline	0.05	0.38	-0.07	7.45	-0.17	0.17	0.00	-0.01 (0.29)
Coal	0.00	0.24	-0.30	15.13	-0.12	0.11	0.00	0.12 (0.00)
Natural gas	-0.05	0.73	1.19	20.90	-0.57	0.58	0.00	0.10 (0.00)

Empirical analysis

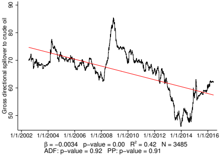
Table: **Volatility spillover between energy commodities**

To/From	Heating oil	Crude oil	Gasoline	Coal	Natural gas	Sum (Excl.)
Heating oil	39.53	31.5	26.49	1.94	0.54	60.47
Crude oil	31.14	39.12	27.22	2.31	0.21	60.88
Gasoline	27.68	28.79	41.29	1.98	0.26	58.71
Coal	4.27	5.06	4.14	86.1	0.42	13.9
Natural gas	2.62	1.87	1.66	0.76	93.09	6.91
Sum (Incl.)	105.23	106.34	100.81	93.11	94.51	
Sum (Excl.)	65.71	67.22	59.52	7.01	1.42	
Net spillover	5.23	6.34	0.81	-6.89	-5.49	
Total Spillover Index:						40.17%

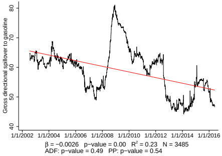
Figure: **Directional spillover to commodity *i*:**



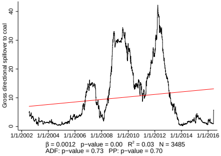
(a) **Heating oil**



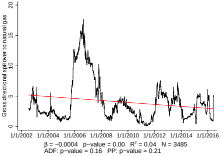
(b) **Crude oil**



(c) **Gasoline**



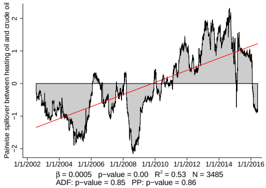
(d) **Coal**



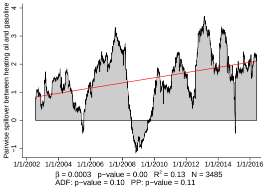
(e) **Natural gas**

Empirical Analysis

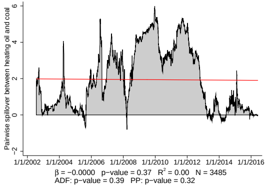
Figure: **Net spillover between commodities:**



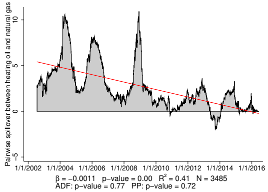
(a) Heating oil and Crude oil



(b) Heating oil and Gasoline

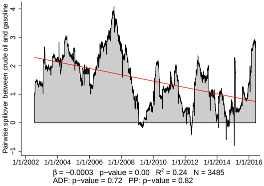


(c) Heating oil and Coal

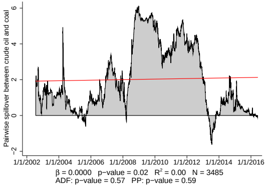


(d) Heating oil and

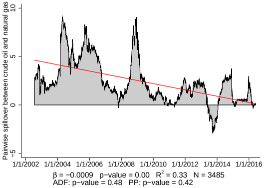
Figure: **Net spillover between commodities:**



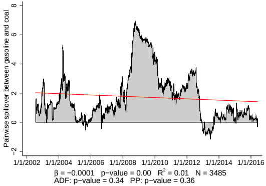
(a) Crude oil and Gasoline



(b) Crude oil and Coal



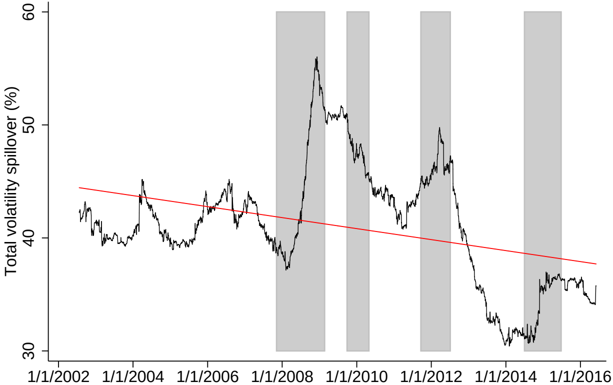
(c) Crude oil and Natural gas



(d) Gasoline and Coal

Empirical Analysis

Figure: **Total spillover index:**



$\beta = -0.0013$ p−value = 0.00 $R^2 = 0.14$ N = 3485
ADF: p−value = 0.84 PP: p−value = 0.85

Conclusion

- Mixed evidence regarding importance of crude oil.
- We show that most of the energy commodities are connected through volatility spillover.
- Understanding the temporal dynamic link between the energy commodities is of particular importance to policymakers, regulatory agencies, and market participants.
- level of spillover is time-variant and appears to be decreasing throughout the sample period.
- Short-term events tends to have major influence on volatility spillover.
- Not all commodities are equally important.
    - For instance, crude oil is a large net transmitter while coal is a net receiver
- During the period of financial and economic turmoil, the total volatility spillover between the energy commodities significantly increases.

Thank you for your attention!

(Any questions?)

Asche, F., A. Oglend, and P. Osmundsen (2012). Gas versus oil prices the impact of shale gas. *Energy Policy 47*, 117–124.

Baffes, J. (2007). Oil spills on other commodities. *Resources Policy 32*(3), 126–134.

Diaz, E. M., J. C. Molero, and F. P. de Gracia (2016). Oil price volatility and stock returns in the G7 economies. *Energy Economics 54*, 417–430.

Diebold, F. X. and K. Yilmaz (2009). Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal 119*(534), 158–171.

Diebold, F. X. and K. Yilmaz (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting 28*(1), 57–66.

References II

Kang, S. H., R. McIver, and S.-M. Yoon (2017). Dynamic spillover effects among crude oil, precious metal, and agricultural commodity futures markets. *Energy Economics 62*(3), 19–32.

Lin, B. and J. Li (2015). The spillover effects across natural gas and oil markets: Based on the VEC–MGARCH framework. *Applied Energy 155*, 229–241.

Liu, X., H. An, S. Huang, and S. Wen (2017). The evolution of spillover effects between oil and stock markets across multi-scales using a wavelet-based GARCH–BEKK model. *Physica A: Statistical Mechanics and its Applications 465*, 374–383.

Serra, T. (2011). Volatility spillovers between food and energy markets: a semiparametric approach. *Energy Economics 33*(6), 1155–1164.