ime and frequency dynamics of connectedness between renewable energy stocks and crude oil prices

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Outline of presentation

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Introduction

Renewable energy has gained considerable ground worldwide as a viable energy alternative due to a combination of factors, such as

- Growing international concern about climate change,
- Fossil fuel depletion,
- Energy security issues,
- Technology innovation, and
- High and volatile prices of petroleum-based fuels.

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Introduction

- According to the Global Status Report published by REN21 (2017), about **19.3%** of global final energy consumption was supplied by renewable energy in **2016**.

- In its World Energy Outlook published in 2017, the International Energy Agency (IEA) - **alternative sources of energy** currently cover about **40%** of the increase in primary demand.

- International Renewable Energy Agency (IRENA) - renewable energy market **increased the total capacity of renewable energy by 8.8%** in 2016.

REN21 refers to Renewable Energy Policy Network for the 21st Century. REN21 is the global renewable energy policy multi-stakeholder network that connects a wide range of key actors.

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Hypothesis

Crude oil remains the **largest source of primary energy**, accounting for **a third** of global energy consumption in 2016 (BP Statistical Review of World Energy 2017).

Whether oil prices are a major driver of the financial performance of green energy companies?

A **positive relationship** between stock prices of clean energy firms and crude oil prices is typically hypothesized (e.g., Henriques and Sadorsky, 2008; Kumar et al., 2012; and Sadorsky, 2012).

Investors and consumers **seek cheaper alternatives to fossil fuels**, rising oil prices should encourage **a substitution effect** away from petroleum-based energy towards alternative energy sources

Another plausible explanation

- Oil price-clean energy (positive) association
- Until recently renewable energy has been far more **expensive than** traditional fossil fuels.
- **High costs of building and installing** renewable energy systems have historically represented a formidable barrier for alternative energy.
- Any significant **oil price drop seriously limit the attractiveness** and economic viability of clean energy projects, leading to a sudden halt in the development of sustainable energy, with the consequent detrimental effect on stock prices of new energy firms.

Objective

- ✓ To analyze the **dynamic interdependence** among stock prices of U.S. renewable energy firms, crude oil prices, and
- ✓ A number of **key financial indicators** (i.e., stock prices of technology and conventional energy firms, U.S. Treasury bond yields, the U.S. default spread and the volatility of the U.S. stock and government bond markets)
- ✓ The **time-frequency connectedness** of Barunik and Krehlik (2018) is applied.
- ✓ Allows one to assess the **magnitude and direction of spillovers** over time and across frequencies simultaneously.

Why frequency domain

- Heterogeneity of **multiple economic agents** interacting in these markets.
- More precisely, market participants operate at diverse time horizons (represented by frequencies) ranging from **seconds to several years**
- Different beliefs, objectives, preferences and institutional constraints as well as **distinct levels of information assimilation and risk tolerance**.
- Economic and financial shocks can propagate through markets producing heterogeneous frequency responses.

Why frequency domain

- Agents with **short investment horizons**, such as **day traders or hedge funds**, are more concerned about the short-run performance of markets
- Make decisions largely based on ephemeral phenomena like **sporadic events** and **psychological factors**.
- Hence, their reaction to shocks occurs principally in the short-run.
- Agents, such as **big institutional investors**, are more interested in the long-run market performance, so that their response to economic and financial shocks is mostly materialized in the long-run.
- Consequently, reasonable to assume the existence of linkages with various degrees of persistence and, hence, different frequency sources of connectedness among oil and financial markets.

Data

Daily closing prices of

- **U.S. renewable energy stocks,**
- **High technology stocks,**
- **Conventional energy stocks,**
- **Crude oil futures contracts,**
- **U.S. 10-year Treasury bond yields,**
- **Default spread and**
- **Volatility of the U.S. stock and Treasury bond markets.**

All the data are gathered from Thomson Reuters DataStream, excepting the default spread, which is obtained from the Federal Reserve Bank of St. Louis.

The sample period covers January 2, 2003 until September 29, 2017, containing a total of 3724 daily observations.

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Data

Wilder Hill Clean Energy Index (ECO)

- To measure the stock market performance of U.S. alternative energy firms.
- ECO was the first index created to track the stock prices of renewable energy companies and has become a benchmark index in this field.
- It is an equal-dollar-weighted index consisting of a set of corporations engaged in activities related to the use of cleaner forms of energy, such as solar power, wind power, hydrogen and fuel cells, biofuels, pollution prevention and related areas.
- This index is quarterly rebalanced and it is composed of 40 companies in the first quarter of 2018.

Data

The NYSE Arca Tech 100 Index

- Formerly known as the Pacific stock exchange (PSE) index
- PSE is a price-weighted index
- Common stocks and ADRs of technology-using companies (e.g. computer hardware, software, semiconductors, aerospace and defense, and biotechnology)
- The success or failure of alternative energy firms often depends on the level of technical development achieved by technology firms.
- Companies in the renewable energy and technology sectors are competing on many occasions for the same resources, access to infrastructures and institutional support.

Data

S&P 500 Oil, Gas & Consumable Fuels sector index (CESI)

- To account for the equity market performance of U.S. conventional energy firms.
- CESI is made up of companies active in integrated Oil and Gas, Oil and Gas exploration and production, Oil and Gas refining and marketing, Oil and Gas storage and transportation, and coal and consumable fuels.
- Therefore, CESI can be considered as a major benchmark for the traditional fossil fuel energy industry.

Figure 1. Time trend of the selected time series

a). ECO

b). PSE

c). WTI crude oil futures

f). VIX

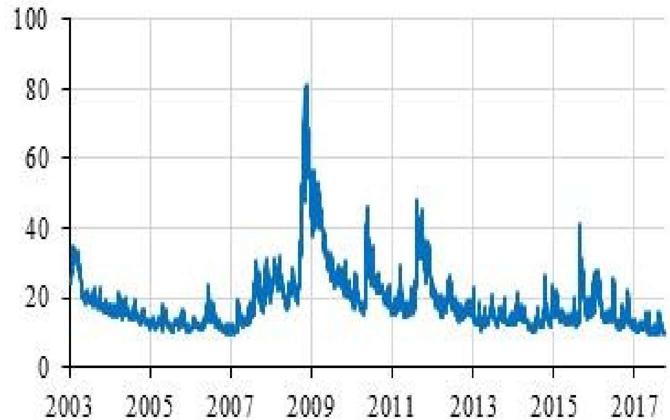

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Table 1. Descriptive statistics for the entire sample

	Mean	Std. Dev.	Skewness	Kurtosis	J-B	ADF	KPSS
ECO	-0.0202	2.0039	-0.3515	8.1550	4198.98***	-57.88***	0.149
PSE	0.0464	1.2266	-0.1790	8.0104	3914.16***	-64.00***	0.076
WTIF	0.0130	2.3730	0.0533	7.0100	2496.22***	-64.31***	0.194
TBY10Y	-0.0005	0.0578	-0.1105	5.9745	1380.10***	-45.87***	0.042
VIX	-0.0043	1.6888	0.7093	23.1992	63604.63***	-28.37***	0.024
TYVIX	-0.0013	0.3210	0.2624	11.4389	11090.01***	-30.68***	0.033

Note: This table presents the summary statistics and unit root tests of the daily series over the period from January 2003 to September 2017. ECO denotes the Wilder Hill Clean Energy index, PSE is the NYSE Arca Tech 100 index, WTIF is the WTI crude oil futures contract, TBY10Y represents the U.S. 10-year Treasury bond yield, and VIX and TYVIX are the expected volatility of the U.S. stock and long-term Treasury bond markets, respectively. J-B refers to the Jarque-Bera test statistics for normality. ADF and KPSS are the statistics of the ADF (Augmented Dickey-Fuller) unit root test and the KPSS (Kwiatkowski-Phillips-Schmidt-Shin) stationarity test, respectively. Log difference returns (multiplied by 100) are used for ECO, PSE, and WTIF, while simple first differences are employed for TBY10Y, VIX and TYVIX. *** indicates statistical significance at the 1% level.

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Table 2. Unconditional correlation matrix

	ECO	PSE	WTIF	TBY10Y	VIX	TYVIX
ECO	1.000					
PSE	0.790***	1.000				
WTIF	0.304***	0.201***	1.000			
TBY10Y	0.307***	0.351***	0.192***	1.000		
VIX	-0.670***	-0.762***	-0.242***	-0.298***	1.000	
TYVIX	-0.174***	-0.161***	-0.068***	0.111***	0.297***	1.000

Note: This table reports the unconditional correlation coefficient between all possible pairs of the daily series over the whole sample period. *** indicates statistical significance at the 1% level.

Methodology

- Spillover index approach put forward by Diebold and Yilmaz (2012).
- Forecast error variance decomposition within the generalized VAR framework
- Barunik and Krehlik (2018) expand the Diebold-Yilmaz approach by including the spectral representation of variance decompositions

Findings

Figure 2. Time-varying total spillover indices

A). Total return spillover index

B). Total volatility spillover index

Note: This figure displays the time-varying behavior of the total return spillover index (Panel A) and the total volatility spillover index (Panel B) among the six variables considered computed using the approach of Diebold and Yilmaz (2012). These dynamic total spillover indices are calculated from the forecast error variance decompositions using a rolling window size of 500 days and a forecast horizon of H=100 days.

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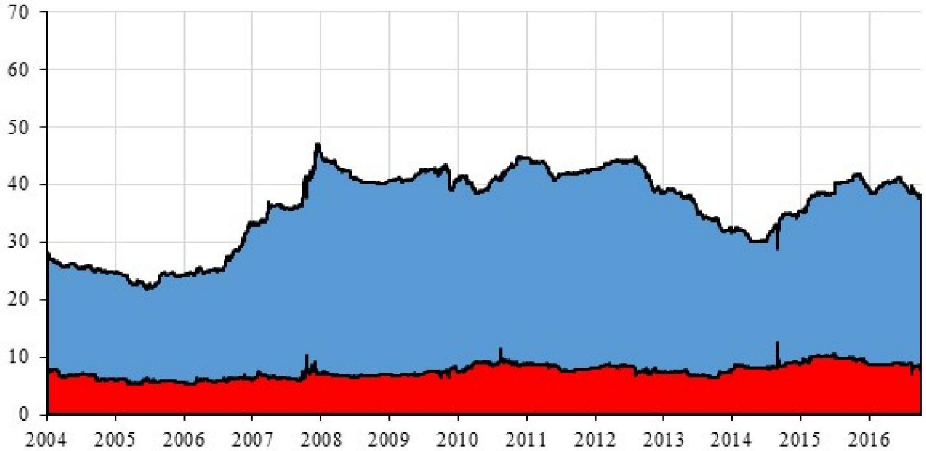
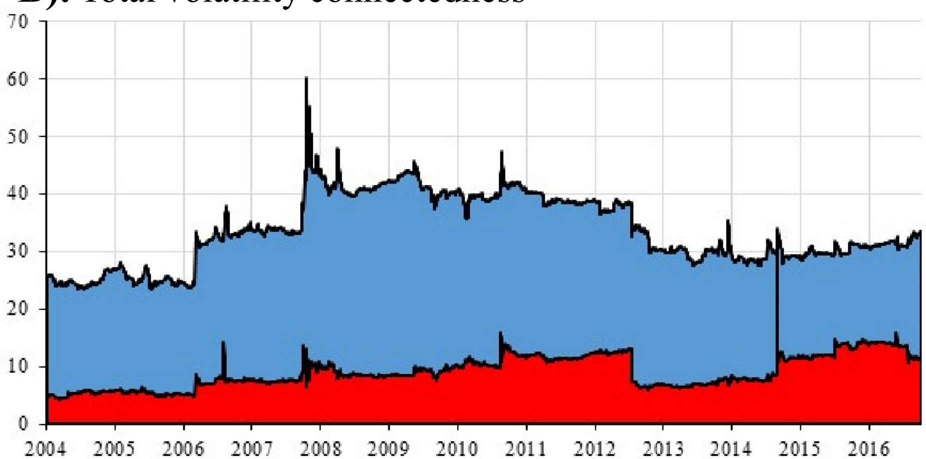
Figure 3. Dynamic total connectedness based the time-frequency method

A). Total return connectedness



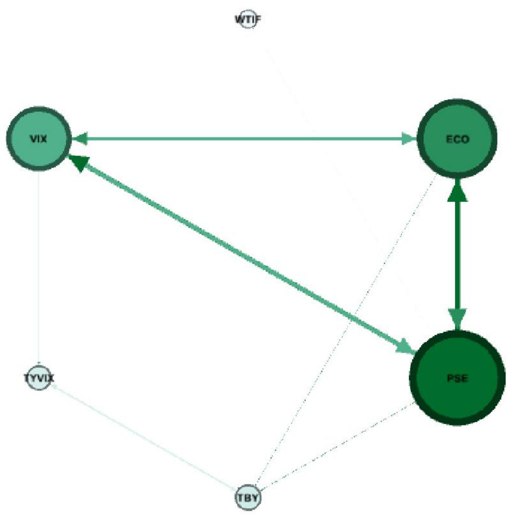
B). Total volatility connectedness



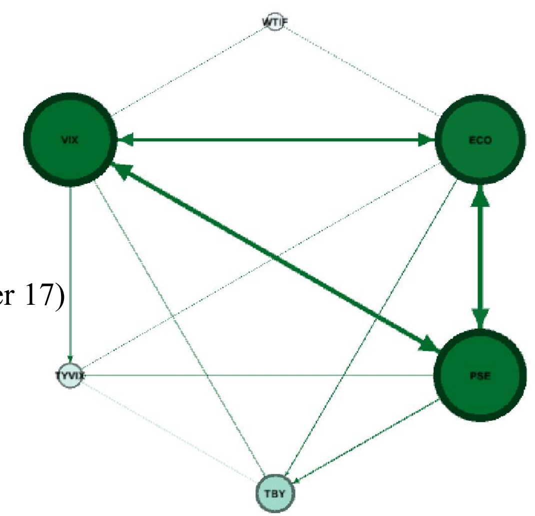
The blue area indicates the connectedness at the higher frequency band, which corresponds to movements up to five days (one week). Instead, the red area reflects the connectedness at the lower frequency band.

Figure 4. Average pairwise directional return connectedness

a). Pre-financial crisis (until July 07)



b). Financial crisis (August 07-March 09)



c). Post-financial crisis (April 09-September 17)

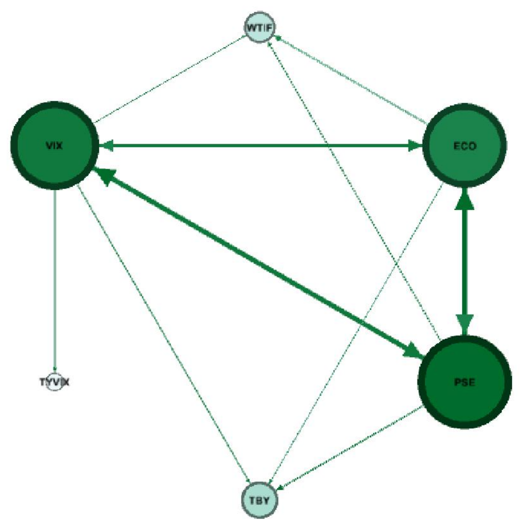
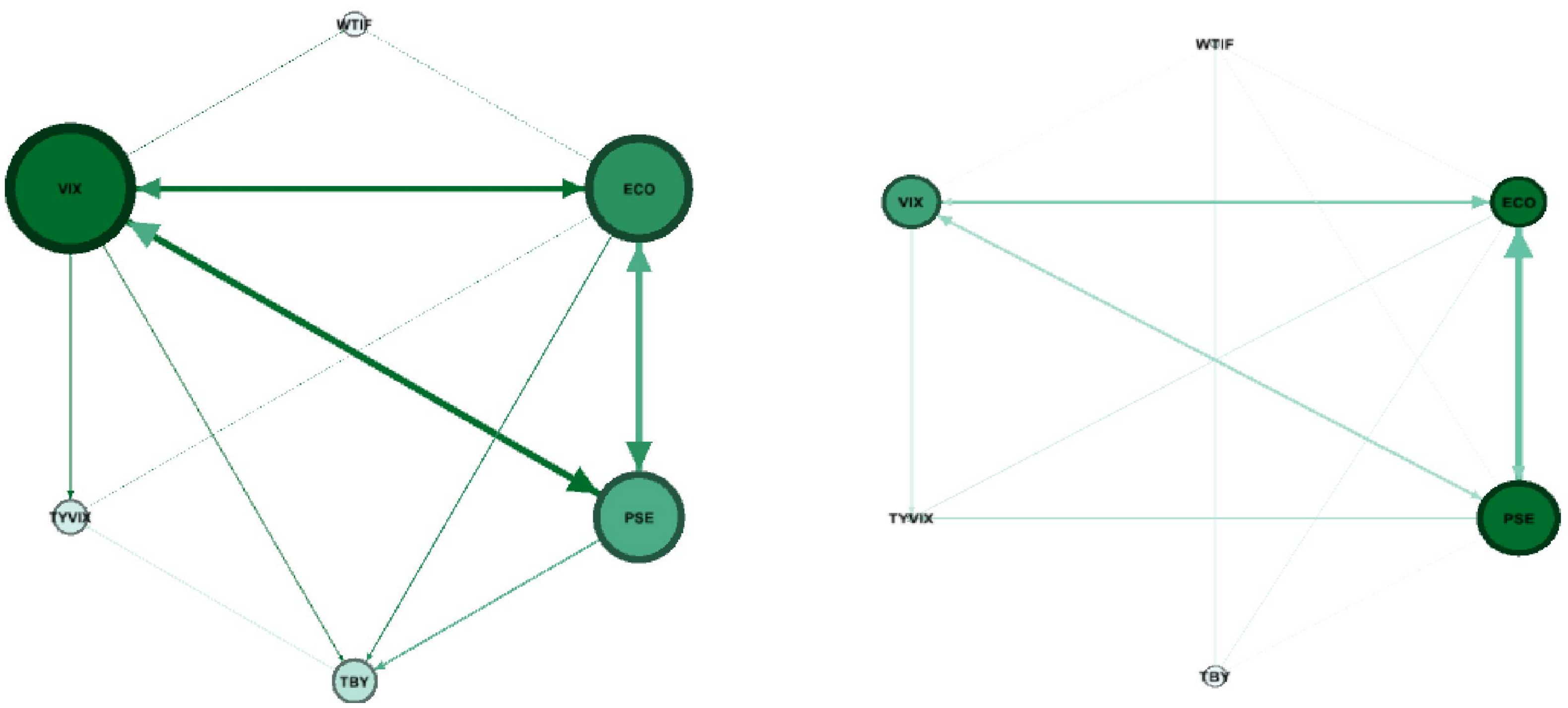


Figure 5. Average pairwise directional return connectedness

Financial crisis (August 07-March 09)



Panel A. Higher frequency band **Panel B.** Lower frequency band

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Discussion of results

- Most of return and volatility connectedness is generated at the higher frequency band (up to 5 days).
- A very fast processing of information by commodity and financial markets
- Increased degree of interconnectedness since the beginning of the financial crisis implies contagion effect (a general re-pricing of risk in the economy)
- In contrast, the much lower return and volatility connectedness at longer time horizons (more than a week)
- Financial and crude oil shocks are generally short-lived
- Development of commodity and financial markets in the long-term is mainly determined by their own fundamentals

Discussion of results

- Crude oil price shocks have hardly any influence on the behavior of equity prices of clean energy firms
- A decoupling of the renewable energy sector from the crude oil market in recent years
- Dynamics of energy markets has changed dramatically - crude oil and renewable energy no longer compete on the same markets.
- Crude oil is basically used to produce transportation fuels, while clean energy is principally utilized to generate electricity.
- **Not direct substitutes**

Discussion of results

- The continual drop in capital, operating and financing costs for alternative energy projects over the last years has increased the margins captured by leading players in the green energy industry.
- Thus, the increasing cost-competitiveness of renewables together with the improved technology for alternative energy production may also have contributed to the decoupling of green energy stocks from the evolution of crude oil prices in recent years.

The only exception in this comparison are liquid transport biofuels, e.g. biodiesel and bioethanol, which directly compete with crude oil products.

Implications

- Implications for various economic agents in terms of portfolio construction and risk management at different investment horizons.
- For short-term investors and portfolio managers, very difficult to find diversification opportunities across crude oil and financial markets,
- Particularly during episodes of heightened financial turmoil, in their attempt to reduce contagion risk.
- Agents with short investment horizons should especially avoid clean energy and high technology stocks in a portfolio due to the significant short-term volatility connectedness

Implications

- Short-term investors could profit from the information regarding the development of crude oil prices contained in stock prices of conventional energy companies.

- In contrast, investors and portfolio managers with longer horizons can benefit from sizeable hedging and diversification opportunities by including crude oil-related financial products in portfolios consisting of alternative energy and/or high technology stocks.

- Policy makers should be aware that the alternative energy sector does not require short- and/or long-term specific policy measures of protection against crude oil price shocks in order to facilitate the transition towards a sustainable energy system.

- Instead, policies promoting renewable energy development should be preferably oriented towards improving investment and green energy-related technology.


THANKS
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