Financial modeling, risk management of energy and environmental instruments and derivatives: past, present, and future

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Abstract
In this preface, we investigate the past, study the present, and look for the future of financial modeling, risk management of energy and environmental instruments, and derivatives based on articles selected in this special issue (SI). We also summarize the significant findings of those articles and identify the research trends.

Keywords Energy market · Financial modelling · Risk management

1 Introduction
Energy markets have witnessed a high degree of price uncertainty since deregulation initiated in the 1970s. This trend has promoted the development of the first exchange-traded energy derivative securities (Fleming & Ostdiek, 1999). Crude oil is a major global energy commodity widely traded around the globe. The price movements of crude oil offer plenty of useful
information related to several markets and variables (Sadorsky, 1999). Consequently, these uncertain oil price movements affect different financial and economic assets (Elekdag et al., 2008). Like other markets, the energy market faces a considerable risk primarily derived from price fluctuations (Sadeghi & Shavvalpour, 2006). Effective portfolio management, together with a foundation of forwarding price, helps to mitigate the risk on the financial economic assets (Halkos & Tsirivis, 2019).

“Global warming and climate change” has been a burning issue for several years due to the spread of excess carbon emissions generated by fossil fuels worldwide. Reduction of carbon emissions globally initiates to propose a rationale for exploring the crucial role of energy and environmental tools (Yao et al., 2019). The financial and economic sectors are closely associated with energy and environmental markets (Nasir et al., 2019). The literature reports some initiatives from authors to address the issues related to the energy market (Maghyereh & Abdoh, 2020; Śmiech et al., 2021; Van Eyden et al., 2019), the environment (Sharif et al., 2019; Waheed et al., 2019; Yao et al., 2019), and risk management (Brenner et al. 2006). Still, there are ample opportunities to study these issues in more detail, which have motivated us to embark on this task and set the theme of this SI titled “Financial Modelling and Risk Management of Energy and Environmental Instruments and Derivatives”.

2 Classification of articles of the special issue

We classify the accepted articles into two broad categories. The first one is “Energy” and the second one is “Environment”. A total of 20 articles have been selected for publication in the SI. There are 18 articles in the “Energy” category, and the rest two belong to the “Environment” category. We further classify the “Energy” into sub-domains like crude oil, energy market, energy efficiency, portfolio management with investment in energy-related stocks, and renewable energy. Figure 1 presents the classification of articles based on application domains.

We further classify the articles based on the methodology used. The major classifications are Statistical and Econometric models, Optimization, Regression, and Econophysics. The outcome clearly shows the dominance of the Statistical and Econometric models, followed by the Optimization techniques. Surprisingly, the regression-based techniques have been less utilized in this SI. Figure 2 shows the classification of the articles based on the techniques applied.

Fig. 1 Classification of accepted articles based on application domains
3 Major findings

We summarize the contents of all the accepted articles based on the application domain classification and following the alphabetical orders of the authors.

3.1 Energy

Studying the dependence structure of energy and stock markets, energy markets instability, the energy commodity movements with other markets, and the effect of the COVID-19 pandemic on the energy markets, etc., attracted the attention of researchers.

3.1.1 Crude oil

Crude oil is a major energy commodity that is widely traded. Exploring the various aspects of crude oil has been a rich domain of research, and this tendency is reflected in this SI. Boubaker et al. (2021) utilize the optimal stopping model to identify the ideal time to sell the WTI crude oil futures. The model offers superior performance compared to the “buy-and-hold” strategy. Chen et al. (2021a) propose a three-factor model for determining a closed-form solution for the Brent crude oil futures. The relationship between the convenience yield and the spot price is positive. They find better results compared to the Schwartz two-factor model. Huynh et al. (2020) analyze how crude oil returns of the U.S. (DCOILWTICO) and Europe (DCOILBRENTEU) impact cryptocurrency prices. They use a non-parametric Econophysics technique called Transfer Entropy for measuring the information flow.

Ji et al. (2021) study the co-movements of the Shanghai crude oil futures with Brent and WTI crude oil futures. It is noticed that the Shanghai crude oil futures are more integrated with the other two reference prices during night sessions. Khalfaoui et al. (2022) explore the impact of the causal nexus of the COVID-19 pandemic on oil prices, economic policy uncertainty, and stock market index of oil-importing and oil-exporting countries. Their study focuses on key oil-importing and exporting nations and observe that the pandemic created a high level of causal impact on oil prices. Shahzad et al. (2021) study the tail dependence structure between the four BRIC stock market and crude oil. They indicate an existence
of multiple tail dependence regimes and conclude that a time-varying dependence structure exists for the oil and BRIC equity markets.

### 3.1.2 Energy market

Ameur et al. (2021) examine the association between futures and spot prices for energy, metal, and agriculture markets, using the NARDL approach. They observe that the futures market witnessed the changes in commodity prices. Antunes et al. (2021) investigate the inter-dependence between spot and futures energy prices and demands, using the Stochastic Hidden Markov model. They find positive significant relationships between the energy prices and demands. Behl et al. (2021) explore the autoregression and bidirectional causality effects between the energy sector’s firm value in India and the ESG score disclosures. The results show no overall bidirectional relationship between the variables. Sinha et al. (2022) analyze the dependency structure of energy commodity and market returns, using the cross-quantilogram correlation approach. The results suggest that the market returns negatively impact energy commodity returns at extreme market conditions.

### 3.1.3 Energy efficiency

Antunes et al. (2020) assess the gain of information for improving energy performances in all U.S. states. They utilize the concepts of the stochastic-entropic analysis, non-linear stochastic optimization, and machine learning algorithms. Their results suggest that California shared a solid common information feedback. Sahu et al. (2021) identify factors that influence energy efficiency for the manufacturing sector, using a regression framework. The findings of this research indicate that productivity and R&D impacted energy efficiency positively, while technology use and tax negatively impacted accomplishing energy efficiency.

### 3.1.4 Portfolio management

Henriques et al. (2022) build a portfolio model for better financial performance for selected stocks from the U.S. energy sector. The two-stage approach combining DEA first and then multi-objective Linear Programming (LP) suggests that oil and natural gas are the sectors that make better investment options. Madani and Fitti (2021) investigate the safe haven and hedge properties of gold against oil and currency prices in normal and extreme market conditions. Using the multifractal correlation measure, the authors observe a significant but negative tail dependence on oil and gold prices for a short duration. Wang et al. (2021) investigate the diversification impacts of energy futures on three traditional commodity futures prices. Using Markowitz’s mean–variance model and Sharpe ratio, the authors find that the crude oil futures are not a good diversifier for any portfolios.

### 3.1.5 Renewable energy

Chen et al. (2021b) identifies the drivers of renewable energy consumption in China, using DEA and Monte Carlo simulation. They find that renewable energy consumption is impacted significantly by population-scale and economic growth at the provincial and national levels. Hille and Lambernd (2021) explore the impacts of economic growth on renewable energy production and final energy use, utilizing a spatial model. They advocate adoptive energy
efficiency strategies for having sustainable economic development. Rizvi et al. (2021) investigate the dynamics of return and risk for investing in green energy stocks. They use the vector autoregression and a variant of the GARCH models. Their findings suggest that the returns from the green energy market are more promising than the Grey energy in the U.S. equity market.

3.2 Environment

Ben Lahouel et al. (2021) study the relationship between environmental performance and income for MENA countries. CO₂ emissions are considered as an undesirable output. Their research findings contradict the Environmental Kuznets curve hypothesis. Chen et al. (2021c) propose a framework to predict the EU’s carbon futures prices. They combine the methods of fuzzy entropy, empirical mode decomposition, and extreme learning machine to achieve the goal. The forecasting performance of the ensemble model is found to be the best.

4 Future research directions

The articles of the SI contribute to the selected themes in terms of methodological development and innovative applications. Researchers have focused more on crude oil and exploring its properties. One-third of the articles (6) under the “Energy” category studied crude oil. Four of the 18 energy-focused articles are related to energy markets, three are related to portfolio management with energy stocks, two are associated with energy efficiency, and three are related to renewable energy. On the contrary, only two out of the overall 20 articles studied environment-related issues. Therefore, we find a clear imbalance in the number of articles in the “Energy” and “Environment” categories. Future research in the following subtopics of the SI may be interesting and useful:

- Trade and sustainable environment
- Environmental risk modeling
- Energy and environmental instruments risk management
- Advances in financial markets of energy instruments
- Energy and environmental derivatives futures trading
- Risk management for energy derivatives using mathematical modeling

Authors of the published articles of this SI relied more on the Statistical and Econometric techniques. Regression and Econophysics-based approaches received less attention. Starting from the second half of the previous decade, artificial intelligence (AI), and machine and deep learning approaches have gotten immense importance in almost every field of research. We find that only one article of the SI (Chen et al., 2021c) utilizes the machine-learning approach. Research may use powerful AI techniques for various prediction-related problems in the field of “Energy” and the “Environment”. It may also be useful to decode the nexus of different underlying variables. Tools like Explainable AI may help to interpret the machine-learning models’ predictions.

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