



# Editorial: Application of Big Data, Deep Learning, Machine Learning, and Other Advanced Analytical Techniques in Environmental Economics and Policy

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## Editorial on the Research Topic

### Application of Big Data, Deep Learning, Machine Learning, and Other Advanced Analytical Techniques in Environmental Economics and Policy

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Environmental science has attracted the attention of more and more researchers around the globe, yet most of the analyses are based on traditional analytical techniques. It is noteworthy that although big data, deep learning, and other machine learning techniques have been applied in many different disciplines, including engineering, computer science, and medical science, these state-of-the-art analytical techniques have not been applied widely in the field of environmental science, nor the areas of environmental economics and management. There are only a few articles based on machine learning, for example, Magazzino et al. (2021a), Magazzino et al. (2021b), Magazzino et al. (2021c), and Magazzino et al. (2021d). Given the powerful capability of these techniques and the increasing availability of big data, their application can supplement existing research by providing a new perspective on environmental economics and management, and providing accurate forecasts and pragmatic policy suggestions.

To fill this gap, the International Society for Energy Transition Studies (ISETS) collaborated with Frontiers in an attempt to promote the application of big data, deep learning, machine learning, and other advanced analytical techniques in analyzing environmental economics and policy by inviting members of the ISETS and other non-member researchers to contribute to a dedicated research topic. The objectives are to facilitate the engagement and the advancement of research centred around energy systems. There are four participating journals for this research topic, namely, *Frontiers in Energy Research*, *Frontiers in Environmental Science*, *Frontiers in Ecology and Evolution*, and *Frontiers in Earth Science*.

The goal of this research topic is to re-examine important environmental economics and management issues by employing cutting-edge research methods based on big data, deep learning, and other machine learning techniques, as well as other advanced analytical methods. Given that many important issues in environmental economics and management are exceptionally complex, and the underlying relationships with the determinants are nonlinear, applying these Frontier research methods may prove particularly valuable because of their capability in modelling various complex and nonlinear relationships.

Thirty-six articles based on significant environmental economics and management issues were published under this research topic. All the analyses are based on state-of-the-art analytical techniques. Most of the authors addressed critical issues from an empirical and quantitative

point of view by revisiting the issues with the application of big data, deep learning, other machine learning techniques, as well as other Frontier techniques. Some authors compared the findings derived from existing research studies based on traditional analytical methods with the proposed Frontier research methods. Moreover, many authors delved into burning issues or heated debates to provide insights into environmental economics and management policy formulation. The articles published under this research topic can be broadly divided into two major areas: environmental protection and energy. However, the focuses of the articles are varied and include many important issues in the two areas.

For the area of environmental protection, some researchers conducted research on the relationship between environmental protection and growth. Xiang et al. examined the impact of economic growth on carbon emission in BRICS countries by using the multivariate wavelet analysis. Khan and Wang examined the short and long-run effects of poverty, income inequality, population, and GDP per capita on carbon emission in Pakistan by applying the Autoregressive Distributive Lag (ARDL) and Non-linear Autoregressive Distributive Lag (NARDL) co-integration approach. Li et al. investigated the relation between carbon emissions and economic growth, industry structure, urbanization, research and development (R&D) investment, use of foreign capital, and growth rate of energy consumption in China based on machine learning.

Other researchers focus on emission analysis. For example, Shum et al. investigated the relative importance of carbon emissions drivers in China by employing the Least Absolute Shrinkage and Selection Operator (LASSO) model in ranking the relative importance of the independent variables. In addition, Ma et al. evaluated the feasibility of using machine learning in carbon emission analysis by employing the Gaussian Process Regression (GPR) algorithm.

Moreover, many authors conducted analyses on policy formulation. Zhang et al. examined carbon neutrality policies and technologies by adopting the scientometric analysis. Shao et al. studied the impact of environmental regulation on industrial structure upgrading by using the Pollution Information Transparency Index (PITI) to measure environmental regulation (ER) and examined the effect of ER on industrial structure upgrading. Feng et al. examined the impact of environmental regulations on China's green total factor productivity by using econometrics analysis and machine learning. Xiao et al. investigated the effect of the green credit policy implemented by the Chinese government on firm-level industrial pollutant emissions by employing a quasi-natural experiment, propensity score matching and the difference-in-difference approach (PSM-DID). Yang et al. studied the relationship between financial inclusion and carbon reduction in Chinese counties. Wu et al. examined the impacts of the new urbanization pilot policy on air quality and related air pollutants. Wang et al. implemented a sharp regression discontinuity (RD) design and assessed air quality control effectiveness in China based on the high-volume big data acquired from 173 cities. Zheng and He evaluated the impacts of two revisions of China's

environmental protection fee on firm performance based on evidence from the stock markets.

Some researchers focus on the emissions of specific industries. For example, Li et al. examined the change in China's construction industry's domestic carbon emission intensity and analyzed the reason behind the change. Chen et al. studied dynamic supervision and control of volatile organic compounds (VOCs) emission from China's furniture manufacturing industry based on big data and the internet of things (IoT).

Given that environmental issue is a significant concern to many countries, some researchers focus on the Belt and Road Initiative (BRI) countries and aim to evaluate the impacts of BRI on various environmental issues. Li et al. offered an evolutionary and counterfactual baseline to assess the environmental impact of BRI based on the distribution dynamics approach and the mobility probability plots (MPPs). In addition, Lu et al. analyzed the environmental risk contagion relations among the BRI countries and the characteristics of their network structure by using social network analysis (SNA).

Other environmental issues are also examined. For example, Xu et al. examined the environmental efficiency of grain production and its spatial effects in China's major grain production areas by the global super-efficiency SBM model and the Spatial Durbin model.

For the field of energy, many researchers focus on electricity. Li and Cao compared the effectiveness of information feedback between emailing electricity bills to households and installing smart meters in promoting electricity conservation by employing empirical survey data from the Chinese General Social Survey and the propensity score matching method. Jin et al. analyzed the effects of sensitive information disclosure and compared the market-clearing results under different scenarios in the Chinese electricity market. He and Gao developed a dual-sector dynamic equilibrium model, and they introduced electricity consumption and water consumption in a growth model using a time series data set from 1950 to 2014 in Guangzhou, China. Jin et al. studied the way to effectively promote compliance management in the electricity market by using an evolutionary game model under two different scenarios, i.e., the scenario without governmental supervision and the scenario with governmental supervision, and explicitly described the strategic behaviours and dynamic evolution process of power enterprises and regulators in the power market. As the mismatch between energy distribution and power load in China can be alleviated by inter-regional and inter-provincial power transactions, Wang et al. studied a method to deal with inter-regional and inter-provincial transaction settlement deviation quantity based on the kernel density-entropy weight approach.

Other authors examined the efficiency, and Li et al. explored the evolution of manufacturing green development efficiency in the Yangtze River Economic Belt by considering the resource inputs and undesirable outputs in the production process using the WSR methodology, the super-SBM model, and the Tobit model. Liu et al. analyzed the impact of government corruption on energy efficiency (EE) in China from the perspective of energy regulations through statistical methods.

**TABLE 1 |** Summary of the methodologies employed in the articles.

Article	Authors	Methodologies
Analysis of Information Feedback on Residential Energy Conservation and the Implications: The Case of China	Zhuangai Li and Xia Cao	Propensity score matching (PSM) method, Logit model
Regional Differences of Manufacturing Green Development Efficiency Considering Undesirable Outputs in the Yangtze River Economic Belt Based on Super-SBM and WSR System Methodology	Gen Li, Ying Zhou, Fan Liu and Tao Wang	SBM Model and Green Development Efficiency Measurement of Manufacturing Industry, Tobit Model
Does Anti-corruption Policy Influence Energy Efficiency in China?	Jie Liu, Jianming Guo, Xiangfeng Liu, Xiao Bai and Farhad Taghizadeh-Hesary	Fixed effects model, panel threshold regression model
Dynamic Risk Assessment of the Overseas Oil and Gas Investment Environment in the Big Data Era	Xuqiang Duan, Xu Zhao, Jianye Liu, Shuquan Zhang and Dongkun Luo	Cloud parameter Bayesian network
Does the New Urbanization Influence Air Quality in China?	Yan Wu, Zhixiang Cui and Cong Hu	Difference-in-difference (DID) method
Tripartite Coordinated Regulation of New Energy Vehicles Based on Dynamic Bayesian Game	Changyu Liu, Yadong Song, Le Chang and Guanglong Dong	Bayesian dynamic game model
Analyzing Information Disclosure in the Chinese Electricity Market	Luosong Jin, Weidong Liu, Xiangyang Wang, Jing Yu and Panting Zhao	Game model
How to Promote Compliance Management in the Electricity Market? An Analysis Based on the Evolutionary Game Model	Luosong Jin, Cheng Chen, Yun Li, Xiangyang Wang and Yuanyuan Cheng	Evolutionary Game Model
Symmetric and Asymmetric Impact of Poverty, Income Inequality, and Population on Carbon Emission in Pakistan: New Evidence From ARDL and NARDL Co-Integration	Salim Khan and Wang Yahong	Autoregressive Distributive Lag (ARDL), Non-linear Autoregressive Distributive Lag (NARDL) co-integration approach
A Method to Deal With Inter-regional and Inter-provincial Transaction Settlement Deviation Quantity Based on Kernel Density-Entropy Weight	Dongfa Wang, Weibin Ding, Feng Gao, Yang Xu and Qin Miao	Kernel function weighting method, improved entropy weight method, deviation electricity responsibility determination model, deviated electric quantity calculation model
The Impacts of Two Revisions of the China's Environmental Protection Fee on Firm Performance: Evidence From Stock Markets	Huan Zheng and Yu He	Difference-in-differences (DID) method
Analysis of the Upgrading Effect of the Industrial Structure of Environmental Regulation: Evidence From 113 Cities in China	Wei Shao, Yufei Yin, Xiao Bai and Farhad Taghizadeh-Hesary	Panel regression model
Evaluating the Impact of Urban Blue Space Accessibility on Housing Price: A Spatial Quantile Regression Approach Applied in Changsha, China	Huang Tuofu, He Qingyun, Yang Dongxiao and Ouyang Xiao	Two-stage instrumental method (2SLS) hedonic model, spatial quantile regression (SQR) model
How Does Target-Based Performance Evaluation Affect the Accuracy of Energy-Saving Data: Evidence From China	Ping Zhang, Tiantian Yu, Shengfeng Lu and Ruting Huang	Difference-in-differences (DID) method
The Main Research Characteristics of the Development of the Concept of the Circular Economy Concept: A Global Analysis and the Future Agenda	Víctor Meseguer-Sánchez, Francisco Jesús Gálvez-Sánchez, Valentin Molina-Moreno and Gonzalo Wandosell-Fernández-de-Bobadilla	Bibliometric analysis
Time-Varying Impact of Economic Growth on Carbon Emission in BRICS Countries: New Evidence From Wavelet Analysis	Lijin Xiang, Xiao Chen, Shuling Su and Zhichao Yin	Decoupling analysis, multivariate wavelet analysis
The Spatial Network Contagion of Environmental Risks Among Countries Along the Belt and Road Initiative	Ling Lu, Kai Fang, Chuan Ming Liu and Cheng Sun	Social network analysis (SNA) model
Driving Factors of CO2 Emissions: Further Study Based on Machine Learning	Shanshan Li, Yam Wing Siu and Guoqin Zhao	Linear regression (LR), least absolute shrinkage and selection operator (LASSO), and Elastic Net (EN), classification and regression Tree, support vector regression, and k-nearest neighbors regression, ensemble methods, artificial neural networks
A Counterfactual Baseline for Assessing Future Environmental Impact: A Case Study of the Belt and Road Initiative	Jing Victor Li, Tsun Se Cheong and Xunpeng Shi	Distribution dynamics approach, mobility probability plot (MPP)
Assessments of Air Pollution Control Effectiveness Based on a Sharp Regression Discontinuity Design –Evidence From China's Environmental Big Data	Ren Wang, Jiaqi Huang, Lizhi Zhang, Yu Xia, Xu Xu and Tongli Nong	Sharp regression discontinuity (RD) design
The Major Driving Factors of Carbon Emissions in China and Their Relative Importance: An Application of the LASSO Model	Wai Yan Shum, Ning Ma, Xiaomei Lin and Tingting Han	Least absolute shrinkage and selection operator (LASSO)
Tracking the Domestic Carbon Emission Intensity of China's Construction Industry: A Global Value Chain Perspective	Xiaoping Li, Yuan Yu, Xunpeng Shi and Xin Hu	Multi-regional input output (MRIO) model, structural decomposition analysis (SDA) method

(Continued on following page)

**TABLE 1 |** (Continued) Summary of the methodologies employed in the articles.

Article	Authors	Methodologies
Stability Analysis of the World Energy Trade Structure by Multiscale Embedding	Leyang Xue, Feier Chen, Guiyuan Fu, Qiliang Xia and Luhui Du	Dynamical similarity analysis
Potential Analysis of the Attention-Based LSTM Model in Ultra-Short-Term Forecasting of Building HVAC Energy Consumption	Yang Xu, Weijun Gao, Fanyue Qian and Yanxue Li	Attentional-based LSTM network (A-LSTM)
The Spatio-Temporal Evolution of China's Hydrogen Fuel Cell Vehicle Innovation Network: Evidence From Patent Citation at Provincial Level	Pei Yu, Feng Jiang, Zhengfang Cai and Yongping Sun	Social network analysis
Effects of Age Dependency and Urbanization on Energy Demand in BRICS: Evidence From the Machine Learning Estimator	Zhou Lu, Mantu Kumar Mahalik, Hemachandra Padhan, Monika Gupta and Giray Gozgor	Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model
The Role of Economic Policy Uncertainty in Renewable Energy-Growth Nexus: Evidence From the Rossi-Wang Causality Test	Zhou Lu, Linchuang Zhu, Chi Keung Marco Lau, Aliyu Buhari Isah and Xiaoxian Zhu	Vector Autoregression (VAR)-based Granger-causality test of Rossi-Wang
Can Machine Learning be Applied to Carbon Emissions Analysis: An Application to the CO <sub>2</sub> Emissions Analysis Using Gaussian Process Regression	Ning Ma, Wai Yan Shum, Tingting Han and Fujun Lai	Gaussian Process Regression (GPR)
Carbon Neutrality Policies and Technologies: A Scientometric Analysis of Social Science Disciplines	Yuan Zhang, Chung-Lien Pan and Han-Teng Liao	Scientometric analysis
Assessing the Environmental Efficiency of Grain Production and Their Spatial Effects: Case Study of Major Grain Production Areas in China	Hanxiao Xu, Bei Ma and Qiang Gao	Global super-efficiency SBM mode, spatial Durbin model
Exposing the Effects of Environmental Regulations on China's Green Total Factor Productivity: Results From Econometrics Analysis and Machine Learning Methods	Junyi Feng, Jianjun Yan and Xia Tao	Least absolute shrinkage and selection operator (LASSO), orthogonal least square regression, threshold model, mediation model
Financial Inclusion and Carbon Reduction: Evidence From Chinese Counties	Zhenkai Yang, Lu Yu, Yinwei Liu, Zhichao Yin and Zumian Xiao	Panel regression
Electricity-Water Consumption and Metropolitan Economic Growth: An Empirical Dual Sectors Dynamic Equilibrium Model	Yiming He and Shaoui Gao	Dynamic equilibrium model
Tracking Cloud Forests With Cloud Technology and Random Forests	Pasky Pascual and Cam Pascual	Random forest model
Dynamic Supervision and Control of VOCs Emission From China's Furniture Manufacturing Based on Big Data and IoT	Zi-Gui Chen, Wei-Ping Wu, Jing Li and Yu-Heng Zeng	Analysis based on application scenarios
Does Green Credit Policy Move the Industrial Firms Toward a Greener Future? Evidence From a Quasi-Natural Experiment in China	Zumian Xiao, Lu Yu, Yinwei Liu, Xiaoning Bu and Zhichao Yin	Propensity score matching and difference-in-difference approach (PSM-DID)

Energy markets has also been studied, for example, Xue et al. analyzed the dynamic trading network structure of the international crude oil and gas market by employing the dynamical similarity analysis at different time scales by inducing a multiscale embedding for dimensionality reduction. Duan et al. studied how the uncertainties and risks of the overseas oil and gas investment environment changed over time and revealed the specific occurrence probabilities of risk on different levels.

Many authors conduct research on the energy transition issue. Using the Bayesian dynamic game model, Liu et al. analyzed the tripartite coordinated regulation for the manufacturers, consumers, and governments in the new energy vehicle (NEV) market. Yu et al. employed social network analysis and patent citation information of hydrogen fuel cell vehicle-related invention patents to construct China's hydrogen fuel cell vehicle innovation network.

As would be expected, renewable energy is also a subject in this research topic. Lu et al. studied the causal relationship between renewable energy consumption and economic growth in four

countries: Brazil, Germany, Japan, and the United States, by using the recent vector autoregression (VAR)-based Granger-causality test of Rossi-Wang. In addition, Lu et al. investigated the effects of age dependency ratio and urbanization on renewable and non-renewable energy consumption in Brazil, India, China, and South Africa.

Some other energy issues are also explored in this research topic. Zhang et al. examined how target-based performance evaluation affects the accuracy of energy-saving data and found that the accuracy of the indicator improves after the central government has included energy intensity in the performance appraisal system for local officials. Xu et al. evaluated the potential of using an attentional-based LSTM network (A-LSTM) to predict heating, ventilation, and air-conditioning (HVAC) energy consumption in practical applications.

Besides the articles above, many researchers conduct research on other important topics. For example, Meseguer-Sánchez et al. analyzed the degree of advancement of the circular economy in the scientific field through a bibliometric analysis. Huang et al. studied the proximity effects of different types and sizes of urban

blue spaces on property value in Changsha metropolis, China. They examined the spatial quantile effect across housing prices by using the two-stage instrumental method (2SLS) hedonic model and spatial quantile regression (SQR). Pascual and Pascual explored the cloud forests by running simulations from a predictive model which is based on artificial intelligence, satellite images, and cloud technology.

**Table 1** shows a summary of the methodologies employed by different authors and it can be observed that many researchers employed big data, deep learning, and other machine learning techniques as well as other advanced analytical methods in analyzing environmental protection, energy, environmental economics and management. The application of these state-of-

the-art analytical techniques offers a new perspective on many significant issues and contributes significantly to the literature.

The Topic Editors, namely Tsun Se Cheong, Xunpeng Shi, Yanfei Li, and Yongping Sun, would like to express their gratitude to the authors for their contribution to this research topic and look forward to working with the research community in research collaboration soon again in the coming future.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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