Modeling and Simulation of Carbon Emission-Related Issues

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1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report in 2013 (IPCC, 2013) [1], global warming is mainly caused by several greenhouse gases, such as carbon dioxide (CO_2), methane, nitrous oxide, and ozone, which are emitted by human activities in a variety of ways. Baroness Anelay, the former UK Minister of State of the Foreign and Commonwealth Office, said: "The threat of climate change needs to be assessed in the same comprehensive way as nuclear weapons proliferation." [2]. In addition, both former Vice-President Al Gore and former President Barack Obama of United States deemed that climate change was a more dangerous threat to the world than international terrorism [3]. The Paris Agreement was signed by 195 nations in December 2015 to strengthen the global response to the threat of climate change, following the 1992 United Nations Framework Convention on Climate Change (UNFCC) and the 1997 Kyoto Protocol. In Article 2 of the Paris Agreement, the increase in the global average temperature is anticipated to be held to well below 2 °C above pre-industrial levels, and efforts are being employed to limit the temperature increase to 1.5 °C above pre-industrial levels [4].

It is estimated that about 72% of the totally emitted greenhouse gases is carbon dioxide (CO_2), 18% methane, and 9% nitrous oxide [5]. Therefore, carbon dioxide (CO_2) emission (or carbon emission) is the most important cause of global warming. The vast majority of anthropogenic carbon emissions come from the combustion of fossil fuels, principally coal, oil, and natural gas, with additional contributions coming from deforestation, changes in land use, soil erosion, and agriculture [6]. The United Nations had made possible efforts on greenhouse gas emissions mitigation. In Article 6 of the Paris Agreement, three cooperative approaches were presented that countries can take in attaining the goal of their carbon emission reduction, including direct bilateral cooperation, new sustainable development mechanisms, and non-market-based approaches [7].

For the carbon emission reduction, several related issues and practical technologies were proposed, such as carbon footprint, carbon tax, cap and trade, carbon right purchasing, carbon emission cost analysis, internal carbon pricing, and so on. Cap and trade is one method for regulating and ultimately reducing the amount of carbon emission [8]. The government sets a cap on carbon emission, limiting the amount of carbon dioxide that companies are allowed to release. Companies that can more efficiently reduce carbon emission can sell any extra permits in the emission market. Thus, the carbon trading markets were set up. Currently there are five trading in carbon allowances: the European Climate Exchange, NASDAQ OMX Commodities Europe, PowerNext, Commodity Exchange Bratislava, and the European Energy Exchange [9].

However, Harvey stated that, "A report released yesterday by a consortium of researchers known as the Global Carbon Project finds that global carbon dioxide emissions from burning fossil fuels are likely to have increased by about 2.7% in 2018, after a 1.6% increase in 2017" [10]. We need to pay special attention to carbon emissions and work out the possible solutions if we still want to meet the targets of the Paris climate agreement. In this urgent time for carbon emission reduction, this special

issue collects 20 related papers concerning carbon emissions from household to various industries by using various models and methods.

2. Summary Information of 20 Papers in the Special Issue

Table 1 shows the summary information of 20 papers in this special issue, including Research Topic, Papers' Author, Method/Model, Research Object, and Industry/Field. From Table 1, we can see that this special issue has 16 carbon emissions-related papers (including five that are carbon tax-related) and four energy-related papers in various industries by using various methods or models. In carbon emissions, it explores household, transportation, and agricultural carbon emissions, carbon emissions reduction, carbon emissions forecasting, and quotas allocation for carbon emissions. In energy, it discusses renewable energy and energy consumption forecasting. These papers will be reviewed in the next section.

3. Review of the Special Issue

3.1. Carbon Emissions

3.1.1. Household Carbon Emissions

Wang et al. [11] used the carbon emissions coefficient method and Consumer Lifestyle Approach (CLA) to calculate the total carbon emissions of households in 30 provinces of China from 2006 to 2015, and adopted the extended Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model to analyze the factors influencing the total carbon emissions of households. The findings indicate that the energy and products' carbon emissions from China's households had demonstrated a rapid growth trend over the past 10 years and primarily derived from residents' high carbon emission categories: residences, food, transportation, and communications.

Huang et al. [12] analyzed the direct and indirect CO_2 emissions by urban and rural households in Beijing, Tianjin, Shanghai, and Chongqing. The results show that urban total household carbon emissions are larger than rural total household carbon emissions for the four megacities. Electricity and hot water production and supply is the largest contributor of indirect household carbon emissions for both rural and urban households. Besides, Beijing, Tianjin, Shanghai, and Chongqing outsource a large amount of indirect carbon emissions to their neighboring provinces.

3.1.2. Transportation Carbon Emissions

Transportation is an important source of carbon emissions in China. Wang et al. [13] analyzed the drivers of carbon emissions in China's transportation sector from 2000 to 2015 by using the Generalized Divisia Index Method (GDIM). The findings show that the added value of transportation, energy consumption, and per capita carbon emissions in transportation have always been major factors affecting China's carbon emissions from transportation. The carbon intensity of the added value and the energy intensity have a continuous effect on carbon emissions in transportation.

3.1.3. Agricultural Carbon Emissions

Zhang et al. [14] utilized decoupling analysis to construct a decoupling index based on carbon footprint and crop yield, and evaluated the relationship between crop production and greenhouse gas emissions using the most modern grain production base in China as a case study. The findings show that a weak but variable decoupling trend occurs from 2001 to 2015, and that there is a weak decoupling across the study period. Besides, rice production constituted 80% of the regional carbon footprint in a crop's life cycle.

Table 1. Summary information of 20 papers in this special issue.

Topic			Paper/Author	Method/Model	Research Object	Industry/Field
1. Carbon Emissions	1.1 Household Carbon Emissions		Wang, Yang, Dong, Cheng, Shang [11]	STIRPAT * Model	30 Provinces of China	Household
			Huang, Zhang, Liu [12]	Input–Output Model	Beijing, Tianjin, Shanghai, and Chongqing of China	Urban and Rural Household
	1.2 Transportation Carbon Emissions		Wang, Zhou, Zhu, Zhang, Zhang [13]	Generalized Divisia Index Method (GDIM).	China	Transportation Industry
	1.3 Agricultural Carbon Emissions		Zhang, Zou, Xu, Yang [14]	Decoupling Analysis	Heilongjiang Land Reclamation Area, China	Agricultural Industry
			Hu, Chen, Huang, Chung, Lan, Chen [15]	PAS 2050-based Life Cycle Analysis (LCA) approach; Life Cycle Inventory (LCI) Analysis; Life Cycle Impact Assessment (LCIA)	Taiwan	Agricultural Industry (Tea)
	1.4 Carbon Emissions Reduction	Carbon emissions reduction for departure aircraft pushback control	Zhu, Li, Sun, Zhang, Wang, Tsai [16]	A Time Prediction Model of aircraft departure taxiing time by using Multivariate Linear Regression	Shanghai Hongqiao Airport, China	Air Transportation Industry
		CO_2 emissions reduction evaluation of Li-ion batteries	Peralta, Vieira, Meunier, Vale, Salles, Carmo [17]	Optimization and simulations using HOMER (Hybrid Optimization Model for Multiple Energy Resources) software	Brazil	Ship Power Industry
	1.5 Carbon Emissions Forecasting		Sutthichaimethee, Kubaha [18]	Relational Analysis Model; VARIMAX-ECM ** Model	Thailand	Industrial Sector
			Zhu, He, Shang, Zhang, Ma [19]	Generalized Divisia Index Model (GDIM); Monte Carlo simulation	China	Power Industry
			Wang, Shang, He, Zhang, Liu [20]	Gray model (GM (1, 1)); Generalized Regression Neural Network (GRNN); Markov Forecasting model; Non-Linear programming	China	Government
	1.6 Quotas Allocation for Carbon Emissions		Meng, Wang, Chen [21]	A Hybrid Trend Forecasting model; A Three-Indicator Allocation model	30 provinces of China	Electric Power Industry

Table 1. *Cont.*

Topic			Paper/Author	Method/Model	Research Object	Industry/Field
2. Carbon Tax		Inventory routing problem with carbon tax	Wang, Tao, Shi [22]	Low-Carbon Inventory Routing Problem (LCIRP) model	China	Refined Oil Logistics
		Carbon tax	Fan, Gao, Chen, Wei, Xu, Lu, Wang, Zhang, Ren, Ulgiati, Dong [23]	3EAD-CGE *** model	China	Agricultural Industry
		Green quality management decision with carbon tax	Tsai [24]	Mathematical Programming	Taiwan	Tire Industry
		Green production planning and control with carbon tax under Industry 4.0	Tsai [25]	Mathematical Programming	Taiwan	Textile Industry
		Carbon taxes and carbon right costs analysis	Tsai [26]	Mathematical Programming	Taiwan	Tire Industry
3. Energy	3.1 Renewable Energy	Renewable energy investment decisions	Li, Wu, Li [27]	Real Options model	China	China Carbon Trading Market
		Life cycle assessment of Buoy–Rope–Drum wave energy converter	Zhai, Zhu, Lu [28]	Life Cycle Inventory (LCI) Analysis; Life Cycle Impact Analysis (LCIA)	China	Wave Energy Industry
		Ethylene economics and production forecasting because of the advent of shale gas	Foster [29]	Vector Error Correction Model (VECM); Multiple Linear Regression Model (MLR)	United States (U.S.)	Ethylene Industry; Natural Gas Industry
	3.2 Energy Forecasting	Energy consumption long-term forecasting	Sutthichaimethee, Kubaha [30]	LT-ARIMAXS Model ****	Thailand	Petroleum Industry

Note: * STIRPAT: Stochastic Impacts by Regression on Population, Affluence, and Technology; ** VARIMAX-ECM: Variance Maximization-Error Correction Model; *** 3EAD-CGE: Economy–Energy–Environmental–Agricultural–Dynamics Computable General Equilibrium; **** LT-ARIMAXS Model: The Long Term-Autoregressive Integrated Moving Average with Exogeneous variables and Error Correction Mechanism mode.

Hu et al. [15] evaluated the environmental impact and carbon footprint of Dongshan tea from Yilan County in Taiwan. The results indicate that climate change has the largest impact upon it, followed by human health, natural resources, and ecosystem quality. It is also found that the environmental impact of Taiwanese tea mainly came from fertilizer input during the raw material phase, electricity use during manufacturing, and electricity use during water boiling in the consumer-use phase.

3.1.4. Carbon Emissions Reduction

Zhu et al. selected Shanghai Hongqiao Airport to explore the control strategy for aircraft departure [16]. In this paper, the influence of the number of departure aircraft on the runway utilization rate, the takeoff rate, and the departure rate of flight departures under the conditions of airport runway capacity constraints are studied. A time prediction model of aircraft departure taxiing time is established in this study by using a multivariate linear regression equation, and the experimental results indicate that without reducing the utilization rate of the runway and the departure rate of flights, implementing a reasonable pushback number for the control of departing aircraft during busy hours can reduce the departure taxiing time of aircraft by about 32%, which will reduce the fuel consumption and pollutant emissions during taxiing on the airport surface.

Peralta et al. [17] analyzed the potential implementation of Li-ion batteries (lithium titanate or lithium iron phosphate) in a platform supply vessel system through simulations using HOMER software (Hybrid Optimization Model for Multiple Energy Resources). They also analyzed the potential emissions reduction for different parts of a mission to an offshore platform for different configurations of the ship power system.

3.1.5. Carbon Emissions Forecasting

Sutthichaimethee and Kubaha [18] used a Relational Analysis Model and VARIMAX-ECM Model to forecast carbon emissions in Thailand for the period between 2018–2029. The research results indicate that carbon emissions will continue to increase steadily by 14.68%, or 289.58 $MtCO_2$eq. by 2029, which is not in line with Thailand's carbon emissions reduction policy.

Zhu et al. [19] adopted Generalized Divisia Index Model (GDIM) and Monte Carlo simulation to explore the influencing factors and scenario forecasts of carbon emissions of the Chinese power industry. The results show that the output scale is the most important factor leading to an increase in carbon emissions in China's power industry from 2000 to 2015, followed by the energy consumption scale and population size. The results also indicate that China's power industry still has great potential to reduce carbon emissions, and the focus can be placed on the innovation and development of energy saving and emissions reduction technology.

Wang et al. [20] used the Gray model (GM (1, 1)), Generalized Regression Neural Network (GRNN), Markov forecasting model, and non-linear programming to evaluate whether China can achieve the 2020 and 2030 carbon intensity targets set by government through energy structure adjustment. The conclusions are that in 2020, the optimal energy structure will enable China to achieve its carbon intensity target under three scenarios. However, in 2030, the optimal energy structure cannot fully achieve China's carbon intensity target under any of the three scenarios.

3.1.6. Quotas Allocation for Carbon Emissions

The electric power industry is the first sector that was introduced into the Carbon Emissions Trading market, which is being constructed in China. Meng et al. [21] utilized a hybrid trend forecasting model and a three-indicator allocation model to propose a quota allocation scheme for carbon emissions in China's electric power industry in 30 provinces from 2016 to 2030. The research findings indicated that nine provinces are expected to be the buyers in the Carbon Emissions Trading market. These provinces are mostly located in eastern China, and account for approximately 63.65% of China's carbon emissions generated by the electric power sector.

3.2. Carbon Tax

Implementing a carbon tax is one method of carbon pricing to mitigate carbon emissions. Wang et al. [22] used Low-Carbon Inventory Routing Problem (LCIRP) model for the inventory routing problem in the distribution process of refined oil with the perspective of carbon tax, and proposed an improved adaptive genetic algorithm combined with greedy algorithm to solve the model. Fan et al. [23] utilized a 3EAD-CGE (economy–energy–environmental–agricultural–dynamics Computable General Equilibrium) model to analyze the degree of carbon tax on the macroenvironment, macroeconomy, and agricultural sectors during the period 2020–2050, in order to investigate whether carbon tax is suitable for China's agricultural-related sectors. This research provides detailed data that supports the views of most people against the imposition of a carbon tax on agricultural-related sectors.

Tsai [24] proposed a green quality management decision model with carbon tax under Activity-Based Costing (ABC) in the tire manufacturing industry. The optimal green quality production portfolio can be selected via a mathematical programming model. Activity-Based Costing (ABC) is used to assess green quality management and production cost. Tsai [9] also considered the environmental issues of carbon emissions, energy recycling, and waste reuse, and proposed a green production planning and control model with carbon tax. Tsai [25] used a mathematical programming model with Activity-Based Costing (ABC) and the Theory of Constraints (TOC) to achieve the optimal product mix to maximize profit under various resource, production, and sale-related constraints.

Cap and trade is one method for regulating and ultimately reducing the amount of carbon emissions. The government sets a cap on carbon emissions for the whole country, and then limited the amount of carbon dioxide that companies are allowed to release. A company that can more efficiently reduce carbon emission can sell any extra permits in the emission market to companies that cannot easily afford reducing carbon emissions. Tsai [26] combined mathematical programming, Theory of Constraints (TOC), and Activity-Based Costing (ABC) to formulate the green production decision model with carbon taxes and carbon right costs under the cap-and-trade scheme, in order to achieve the optimal product-mix decision under various constraints. This paper proposed three different scenario models with carbon taxes and carbon right, and used them to evaluate the effect on profit of changes in carbon tax rates.

3.3. Energy

3.3.1. Renewable Energy

Renewable energy is safe, abundant, and clean to use when compared to fossil fuels. However, many forms of renewable energy are location-specific and require storage capabilities. Even regarding this, renewable energy has great potential investment value. Li et al. [27] adopted a real option model considering carbon price fluctuation as a tool for renewable energy investment. Considering optimal investment timing and carbon price, the model introduces a carbon price fluctuation as part of the optimization paper.

Zhai et al. [28] applied Life Cycle Inventory (LCI) analysis and Life Cycle Impact Analysis (LCIA) to conduct a life cycle assessment (LCA) study for a buoy–rope–drum (BRD) wave energy converter (WEC).

Foster [29] utilized the Vector Error Correction model (VECM) and Multiple Linear Regression model (MLR) to projects the United States' (U.S.) future ethylene supply in the context of two megatrends: the natural gas surge and global climate change. The results indicated that the availability of shale gas in the U.S. and low-priced feedstocks from natural gas relative to crude oil were key factors influencing ethylene supply.

3.3.2. Energy Forecasting

Sutthichaimethee and Kubaha [30] applied LT-ARIMAXS (the Long Term-Autoregressive Integrated Moving Average with Exogeneous variables and Error Correction Mechanism model) to conduct energy consumption long-term forecasting for the petroleum industry in Thailand.

4. Concluding Remarks

Since carbon emissions reached an all-time high in 2018, where global carbon dioxide emissions from burning fossil fuels have increased by about 2.7% in 2018, after a 1.6% increase in 2017. We need to pay special attention to carbon emissions and work out the possible solutions if we still want to meet the targets of the Paris climate agreement. This special issue collects 16 carbon emissions-related papers (including five that were carbon tax-related) and four energy-related papers in various industries by using various methods or models. Although this special issue did not fully satisfy our needs, it still provides abundant related material for energy conservation and carbon emissions reduction. However, there still are many research topics waiting for our efforts to study to solve the problems of global warming.

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