International Journal of Business Ethics in Developing Economies
12 (1) 2023, 11-18
http://publishingindia.com/ijbede/

An Empirical Investigation of the Relationship between Economic Development, Industry 4.0 and Carbon Emission: Evidence from Global 50 Countries

Asha Sharma*

Abstract *Purpose: The main purpose of the paper is to analyse the factors influencing carbon emissions in global countries. Research Design, Data and Methodology: Factor analysis has been applied to reduce factors and to find the most influencing factor in carbon emissions and the chi-square test has been used to test the hypotheses. Result: Among the nine selected factors, three factors, namely the nature of industry & density, demographic change, and economic development, were found to have high carbon emissions. It is found that there is a significant association between industrialisation and carbon emissions among selected Asian countries. However, no significant association has been found between demographical change, economic development and carbon emissions among selected Asian countries. There, industrialisation is considered one of the most important factors responsible for carbon emissions. Conclusion: Growing consumption of energy and industrialisation both support economic growth while harming the environment. It has been determined that one of the key factors affecting carbon emissions and climate change is industrialisation. The two critical variables need to be balanced. Industry 4.0 is anticipated to enable industrialisation to advance without increasing carbon emissions.*

Keywords *Carbon Emission, Carbon Per Capita, Economic Development, Industry 4.0*

JEL Classification Code: O01, O014, O044

INTRODUCTION

Global warming, overutilisation of natural resources and variations in climate have had a severe impact on human life. Humans can employ technology, for whatever it takes towards their comfort in the era of Industry 4.0, which includes robotics, automation and machine learning. However, they remain helpless in preventing the excessive use of natural resources and greenhouse gas emissions.

Since the early 21st century, rapid climate change has become a burning issue due to its negative impact on ecosystems (Malhi et al., 2020). Urbanisation and energy use are both increasing at an accelerated rate, which is causing the environment to degrade (Consumption & Emission, 2015). Climate change and carbon emissions are major problems that are attracting worldwide attention (Jiang et al., 2018). The world has been faced with significant climate change. That's why it becomes necessary to identify the factors influencing the extent of carbon emission. Also, to explore, analyse and predict the trends in the development of carbon emission intensity in order to achieve the goal of reducing carbon emissions (Sun & Huang, 2022). To manage the ever-increasing regulations and protocols given at the international level, high-emitting countries have been warned to set up goals to reduce carbon emissions (Lin & Jia, 2019).

Energy consumption and per capita carbon emissions of the transportation industry were the main factors leading to the increase in carbon emissions, and energy carbon emission intensity was the key factor to reduce carbon emissions. (Wang et al., 2018) The surge in energy consumption and carbon dioxide ($CO_{2)}$ emissions is exacerbating global warming (Yang et al., 2018). Other factors responsible for climate change are rapid urbanisation and massive energy consumption. There is tremendous pressure to reduce greenhouse gases (Yuanzheng Li et al., 2021). Therefore, it is necessary to establish the linkage between income and emissions of intra-national greenhouse gases.

Out of various approaches to reduce greenhouse gases, one such technique, emissions trading, is the best way to mitigate climate change. However, monitoring, estimating and verifying actual emissions are still required. Also, the carbon tax has been applied to high-polluting companies to force them to reduce their emission levels (Shawn Lobo and Professor 2016).

* Assistant Professor, Department of Accountancy and Business Statistics, University College of Commerce & Management Studies, Mohanlal Sukhadia University, Udaipur, Rajasthan, India. Email: drashasharma.sharma07@gmail.com

REVIEW OF LITERATURE

A review of the literature was conducted in the area around carbon emissions. The research paper published in national and international journals, books, magazines and websites of the World Bank has been studied, to understand the existing work done. Several international literatures were reviewed:

The paper is based on analysing the factors influencing CO_2 emissions. Finding climatic factors based on socio-economic factors are one of the key aspects involved in effectively reducing greenhouse gas emissions. Mainly, the STIRPAT model (Stochastic Impacts by Regression on Population, Affluence and Technology) has been used to investigate the mechanism driving emissions by the co-action of natural and socio-economic factors. Overall main influencing factors are urbanisation rate, gross domestic product (GDP) per capita, population, energy intensity, trade openness, cooling degree days, mean temperature anomaly and economic development (Yang et al., 2018).

It is concluded in the study that per capita GDP, urbanisation level and energy consumption structure have positive effects on the carbon emissions of the transportation industry in Belt & Road Initiative (BRI) countries, while other factors like technology level and trade openness have a negative impact on carbon emissions of the transportation industry (Zhu & Gao, 2019).

In other studies, a strong correlation between energy usage and per capita income (i.e. economic growth) has been found, that poses a dilemma for African economies in their drive for growth. It is suggested that as African countries seek more development without contributing to carbon emissions, governments should invest more in renewable energy (Adeleye et al., 2021).

China is one of the major carbon emission traders. This paper explains the functioning of carbon emission trading schemes and the relationship between coal prices and the stock index in China. The results indicate that carbon price is mainly affected by its historical price. Coal and oil prices have negative effects on carbon prices (Jiang et al., 2018).

The next research comprehensively analyses the factors influencing carbon emissions from the Chinese ISI. It analyses this issue from the industrial chain perspective and provides a new research scope for future simulation model studies (Li et al., 2019).

At the same time, some papers have identified the influencing factors of carbon price fluctuations. The study is based on the Beijing carbon trading market in China to understand the influencing factors of carbon price fluctuations and predict future carbon prices. The gray correlation technique is employed to measure the rationality of the selected factors affecting carbon price fluctuations. genetic algorithm (GA) optimized extreme learning machine (ELM) model is found the best prognosis effect (Yanmei Li & Song, 2022).

To achieve carbon neutrality, the European Union Emissions Trading System is assumed to be the most important system. Carbon prices have fluctuated due to the coronavirus disease 2019 pandemic. The driving factors of the carbon price, which help maintain the stability of the carbon emissions trading market for carbon neutrality, are explored in the research. Bai–Perron structural break test has been applied to analyse the factors that influence carbon price (Dong et al., 2022).

The paper focuses on household energy consumption and income elasticity. The main variables applied in the study are carbon intensity and income categories of the counties. Cross-country inverted-U relationship is revealed between per capita GDP and emissions intensity in consumption pattern of income effect (Caron & Fally, 2022).

This paper describes the impact of changes in income inequality on CO_2 emissions in OECD countries. The relationship between economic growth and carbon emissions has been found. Gini coefficients and panel data estimation techniques have been used to measure these relationships. A positive association is found between an increase in top-income inequality and carbon emissions (Hailemariam et al., 2020).

The results of the study indicate that the number of manufacturing industries has a positive and significant impact on environmental degradation, while the amount of government spending on the environment, households and shipping activities does not (Azwardi et al., 2022).

Identification of Research Gap

A systematic mapping of research enables an understanding of the current research gaps. By reviewing the paper, it seems that most of the research has been conducted on carbon trading pricing, carbon trading mechanism or its accounting and taxation part. Identifying factors associated with greenhouse gases is found limited.

- What are the factors that affected the carbon emission level the most?
- Is there any discrimination found between the countries emitting high and low carbon based on region, industry 4.0 and economic development?

METHODOLOGY

The research work is based on secondary data. Data relating to carbon emission, income group and region has been gathered through the World Bank website (data.worldbank.org). Carbon Emission Global share of the Top 50 Countries, out of a total of 270 global countries has been identified for further research purposes. Global mean CO_2 per capita consumption has been calculated.

All the selected countries have been divided into high and low carbon-emitting countries according to CO_2 per capita consumption. Around 21 countries are found above the mean and considered as high carbon-emitting countries and the remaining 29 countries as low carbon- emitting countries.

The average of all available industries, that is, coal, oil, flaring and gas has been applied for the categorisation of countries into high and low industrialisation levels.

Statistical Tools and Techniques

Factor analysis and chi-square test have been applied to prove the hypotheses.

Objectives of the Study

- To know the factor influencing the carbon emission level.
- To understand the relationship between carbon emissions and economic development.
- To understand the relationship between carbon emission and region.
- To understand the relationship between carbon emission and industrialisation.

Hypotheses of the Study

- H01: There is no significant association between economic development and carbon emission among selected countries.
- H02: There is no significant association between region and carbon emission among selected countries.
- H03: There is no significant association between industrialisation and carbon emission among selected countries.

RESULT AND DISCUSSION

Factor Analysis

Based on the review of the literature these nine factors are found responsible for influencing carbon emissions. For the reduction of the number of factors, factor analysis is applied. Its results are presented in a concise manner, presenting finalised three factors (Sharma et al., 2022).

Table 1: Disclosure of Derived Three Factors

F1		F2		F3	
Variable 1	**Loading**	**Variable 2**	**Loading**	**Variable 3**	**Loading**
Oil	**.970**	**Region**	**0.843**	**Income**	**0.968**
Gas	**.947**	**Global Share**	**0.834**		
Population	.936				
Cement	.930				
Flaring	.919				
CO_2 per Capita	0.806				

Source: Own prepared based on SPSS result.

Table 1 depicts the disclosure of derived three factors. As per the result of factor analysis, all the remaining variables have been divided into three factors, naming nature of industry and density, demographical change and economic development, out of nine selected factors.

Table 2: Naming of the Factors

Factor No.	Name of the Factor
F1	Nature of Industry & Density
F2	Region
F3	Economic Development

Table 2 mentions the name of the factors. After finding the appropriate factors, further study was conducted to examine various hypotheses. The objective was to identify whether all three factors equally affect the high and low-carbon emitting countries.

H01: There is no significant association between region and carbon emission among selected countries.

All the selected countries have been divided into three categories, that is, East Asia and Pacific, Europe and Central Asia and South Asia based on region.

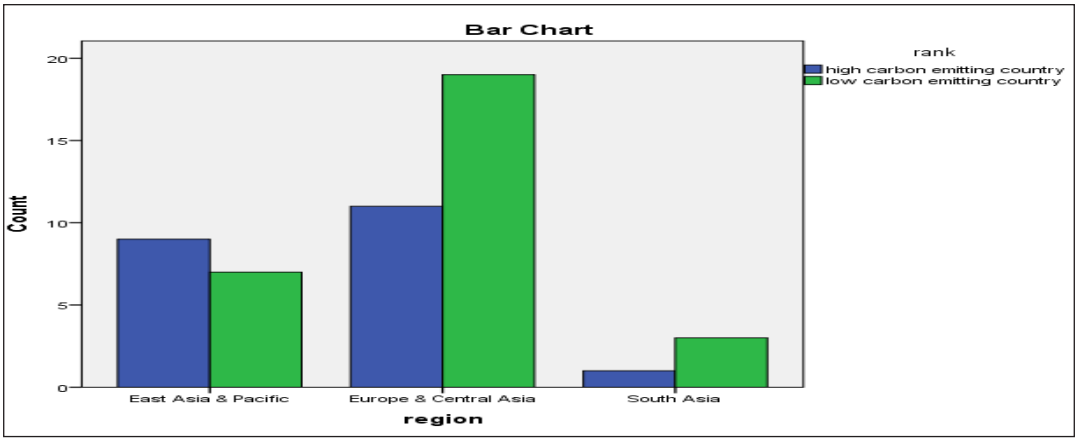

Chart 1: Bar Chart Showing Region and Carbon Emitting Countries

Table 3: Crosstab

			Rank		Total
			High-Carbon Emitting Country	Low Carbon Emitting Country	
Region	East Asia & Pacific	Count	9	7	16
		Expected Count	6.7	9.3	16.0
	Europe & Central Asia	Count	11	19	30
		Expected Count	12.6	17.4	30.0
	South Asia	Count	1	3	4
		Expected Count	1.7	2.3	4.0
Total		Count	21	29	50
		Expected Count	21.0	29.0	50.0

Chart 1 and Table 3 indicate that the majority of selected upper and lower middle-income countries are equally carbon-emitting countries. However, this ratio is reversed in high-income group countries. The number of high carbon-emitting countries is eight, while it is 16 with low emissions in the high-income group. It may be one of the reasons that these countries are in the developing process and need more energy consumption in manufacturing.

Table 4 Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided)			Monte Carlo Sig. (1-sided)		
				Sig.	99% Confidence Interval		Sig.	99% Confidence Interval	
					Lower Bound	Upper Bound		Lower Bound	Upper Bound
Pearson Chi-Square	1.423[a]	2	.491	.566[b]	.553	.579			
Likelihood Ratio	1.433	2	.488	.566[b]	.553	.579			
Fisher's Exact Test	1.484			.566[b]	.553	.579			
Linear-by-Linear Association	1.144[c]	1	.285	.317[b]	.305	.329	.184[b]	.174	.194
N of Valid Cases	50								

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.04.

b. Based on 10000 sampled tables with starting seed 2000000.

c. The standardized statistic is -1.070.

Due the failure of the assumption of having an expected count of less than 5, instead of chi-square test, Fisher's exact test has been applied to find the association between both the variables.

The result so obtained indicate that the model is a good fit $\chi 2$ (2, N=50)=1.423, p>0.05 as the value of p=0.488. So, the hypothesis is accepted. It means that there is no significant association between region and carbon emission among selected countries. Demographical change (region) has not been found directly associated with or a significant factor affected by carbon emission.

H02: There is no significant association between economic development and carbon emission among selected global countries.

Data regarding the income group of selected global countries have been taken from the World Bank website where selected countries are categorised into high, upper-middle and lower-middle income groups.

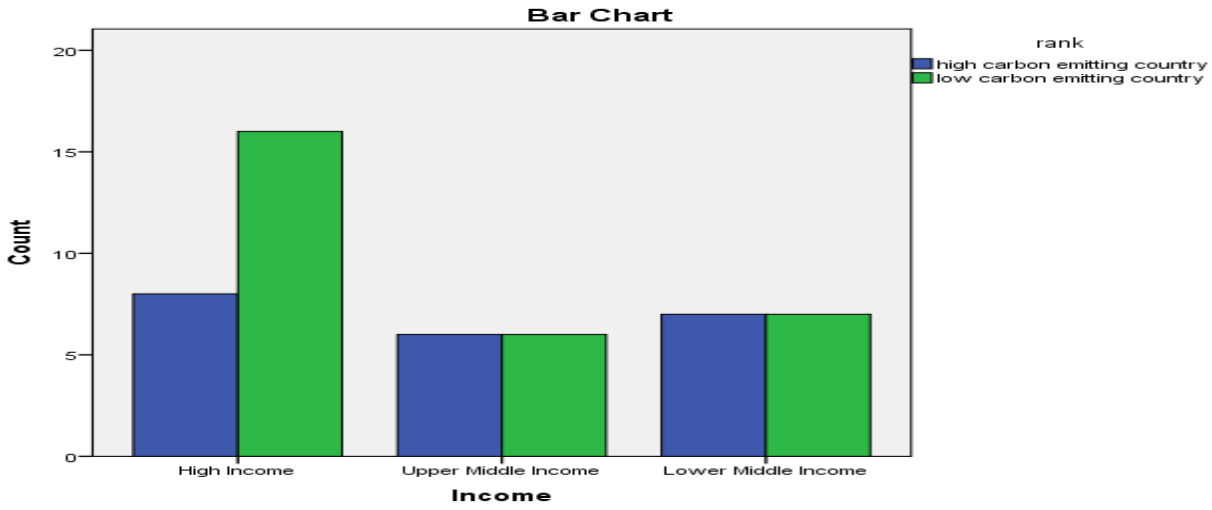

Chart 2: Bar Chart Showing Incomes and Carbon-Emitting Countries

Table 5: Crosstab

			Rank		Total
			High Carbon Emitting Country	**Low Carbon Emitting Country**	
Income	High- Income	Count	8	16	24
		Expected Count	10.1	13.9	24.0
	Upper Middle Income	Count	6	6	12
		Expected Count	5.0	7.0	12.0
	Lower Middle Income	Count	7	7	14
		Expected Count	5.9	8.1	14.0
Total		Count	21	29	50
		Expected Count	21.0	29.0	50.0

Chart 2 and Table 5 indicate that most of the selected upper and lower middle-income based countries are equally carbon-emitting countries. This ratio is reversed in high-income group countries. The number of high carbon-emitting countries is eight, while it is 16 with low emissions in the high-income group. It may be one of the reasons that these countries are in the developing process and need more energy consumption in manufacturing.

Table 6: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.423[a]	2	.491
Likelihood Ratio	1.433	2	.488
Linear-by-Linear Association	1.144	1	.285
N of Valid Cases	50		

a. 0 cells (0.0%) have an expected count of less than 5. The minimum expected count is 5.04.

The result so obtained indicate that the model is a good fit $\chi 2$ (2, N=50)=1.423, p>0.05 as the value of p=0.491. So the hypothesis is accepted. It means that there is no significant association between economic development and carbon emission among selected Asian countries. Economic development is not found directly associated with or a significant factor affected by carbon emission.

H03: There is no significant association between industrialisation and carbon emission among selected Asian countries.

All the selected countries have been divided into two categories, that is, the high and low-industrialised countries based on industrialisation.

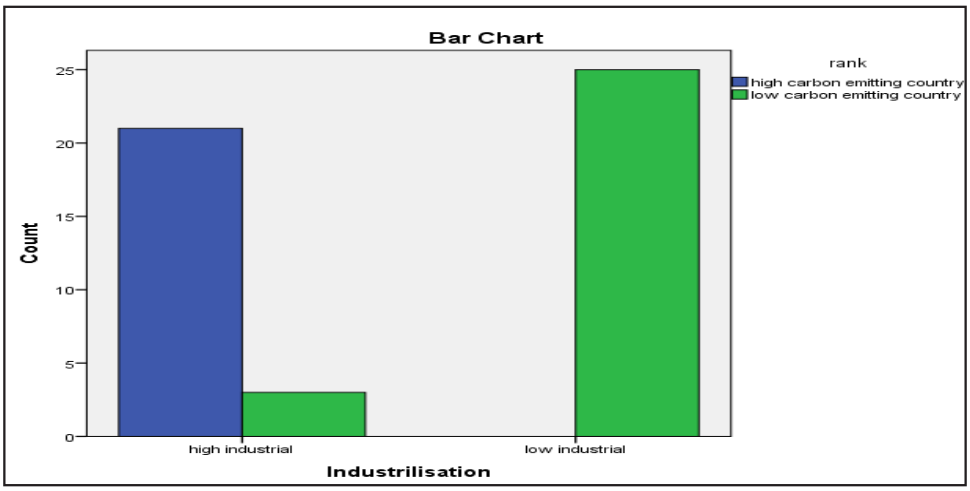

Chart 3: Bar Chart Presenting Industrialisation and Carbon Emitting Countries

Table 7: Industrialisation * Rank Cross Tabulation

			Rank		Total
			High Carbon Emitting Country	Low Carbon Emitting Country	
Industrialization	High- industrial	Count	10	0	10
		Expected Count	4.3	5.7	10.0
	Low industrial	Count	11	28	39
		Expected Count	16.7	22.3	39.0
Total		Count	21	28	49
		Expected Count	21.0	28.0	49.0

Chart 3 and Table 7 indicate the ratio of the selected countries based on carbon emission countries, as well as, the industrialisation category. It shows that highly industrialised countries emit high levels of carbon, while only a limited number of countries emit low levels of carbon. On the other hand, low-industrialised countries are in the category of low carbon emissions.

Table 8: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	38.281[a]	1	.000		
Continuity Correction [b]	34.792	1	.000		
Likelihood Ratio	48.840	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	37.500	1	.000		
N of Valid Cases	49				

a. 0 cells (0.0%) have an expected count of less than 5. The minimum expected count is 10.29.

b. Computed only for a 2x2 table.

The result so obtained indicate that the model is a not good fit $\chi 2$ (1, N=49)=38.281, $p<0.05$ as the value of p=0.000. So the hypothesis is rejected. It means that there is a significant association between industrialisation and carbon emissions among selected Asian countries. Industrialisation is the factor that causes carbon emissions. Therefore, industrialisation has been considered as one of the most important responsible factors for carbon emissions.

CONCLUSION

The industrialised nations are more in the process of development and they are the thriftiest in the entire world (Sharma, 2022).

Industrialisation and energy use is accelerating, which is promoting economic expansion but also causing environmental damage. Carbon emissions are the primary driver of global climate change. It has become a challenging problem of this century at the global level.

Anthropogenic CO_2 and other greenhouse gas emissions are responsible for climate change. The effects of climate change, which affect both natural and human systems, include global average surface temperature increases, extreme weather events, changing precipitation patterns, increasing sea levels and ocean acidification. These risks will eventually affect people's lives, especially those of marginalised groups like women, children, and the elderly, as resources, food, and water become scarcer. The other sustainable development goals are impacted by these effects, which typically make it more difficult to achieve them (https://sdgcompass.org/sdgs/sdg-13).

Carbon emissions have emerged as one of the most pressing challenges in the current scenario. It is essential to control this problem at the global level. It is required to make efforts from time to time to reduce greenhouse gases. The main purpose of the study is to know the factor influencing the carbon emission level. Carbon Emission Global share of the top 50 countries out of a total of 270 global countries has been identified for further research purposes.

It has been found that three important factors equally influence the countries with high and low carbon emissions. In further analysis, it is disclosed there is a significant association between industrialisation and carbon emission among selected Asian countries. No significant association has been found between demographical change, economic development and carbon emission among selected Asian countries. Thus, industrialisation has been considered one of the most important factors responsible for carbon emissions.

Industrialisation and energy use is accelerating, promoting economic expansion and causing environmental damage. It is concluded that industrialisation is one of the important factors influencing carbon emissions and climate change. There is a need for balance between the two controversial variables. It is expected that Industry 4.0 enable industrial development without an increase in carbon emissions.

ACKNOWLEDGEMENT

I acknowledge the authors whom I cite for the literature.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

REFERENCES

Adeleye, B. N., Osabohienid, R., Lawal, A. I., & De Alwis, T. (2021). *Energy use and the role of per capita income on carbon emissions in African countries*. doi:https://doi.org/10.1371/journal.pone.0259488

Sharma, A. (2022). Analyzing potential of sustainable development goals (SDG) in reducing economic

inequalities. *International Journal of Scientific Research in Multidisciplinary Studies, 8*(11), 58-62.

Azwardi, A., Sukanto, S., Nazeli, A., & Arika, K. (2022). Environmental quality in Indonesia: Disruption by economic agents. *Asian Journal of Business Environment*, *12*(1).

Caron, J., & Fally, T. (2022). Per capita income, consumption patterns, and CO_2 emissions. *Journal of the Association of Environmental and Resource Economists*, *9*(2), 235-271. doi:https://doi.org/10.1086/716727

Cheng, B., Dai, H., Wang, P., Zhao, D., & Masui, T. (2015). Impacts of carbon trading scheme on air pollutant emissions in Guangdong Province of China. *Energy for Sustainable Development*, *27*. doi:https://doi.org/10.1016/j.esd.2015.06.001

Consumption, E., & Emission, C. O. (2015). *An empirical investigation of the relationship between economic growth: An empirical investigation of the relationship between economic growth, urbanization, energy consumption, and CO_2 emission in GCC countries: A panel data analysis*. doi:https://doi.org/10.5539/ass.v11n21p270

Dong, F., Gao, Y., Li, Y., Zhu, J., Hu, M., & Zhang, X. (2022). Exploring volatility of carbon price in European union due to COVID-19 pandemic. *Environmental Science and Pollution Research*, *29*(6), 8269-8280. doi:https://doi.org/10.1007/s11356-021-16052-1

Hailemariam, A., Dzhumashev, R., & Shahbaz, M. (2020). Carbon emissions, income inequality and economic development. *Empirical Economics*, *59*(3), 1139-1159. doi:https://doi.org/10.1007/s00181-019-01664-x

Jiang, Y., Lei, Y. L., Yang, Y. Z., & Wang, F. (2018). Factors affecting the pilot trading market of carbon emissions in China. *Petroleum Science*, *15*(2). doi:https://doi.org/10.1007/s12182-018-0224-3

Li, Yanmei, & Song, J. (2022). Research on the application of GA-ELM model in carbon trading price – An example of Beijing. *Polish Journal of Environmental Studies*, *31*(1). doi:https://doi.org/10.15244/pjoes/138357

Li, Yuanzheng, Wang, W., Wang, Y., Xin, Y., He, T., & Zhao, G. (2021). A review of studies involving the effects of climate change on the energy consumption for building heating and cooling. *International Journal of Environmental Research and Public Health*, *18*(1), 40. doi:https://doi.org/10.3390/ijerph18010040

Li, Z., Dai, H., Song, J., Sun, L., Geng, Y., Lu, K., & Hanaoka, T. (2019). Assessment of the carbon emissions reduction potential of China's iron and steel industry based on a simulation analysis. *Energy*, *183*. doi:https://doi.org/10.1016/j.energy.2019.06.099

Lin, B., & Jia, Z. (2019). What are the main factors affecting carbon price in emission trading scheme? A case study in China. *Science of the Total Environment*, *654*. doi:https://doi.org/10.1016/j.scitotenv.2018.11.106

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: Threats, opportunities and solutions. In *Philosophical Transactions of the Royal Society B: Biological Sciences* (vol. 375, no. 1794). doi:https://doi.org/10.1098/rstb.2019.0104

Sharma, A., Bhanawat, S. S., & Sharma, R. B. (2022). Adoption of blockchain technology based accounting platform. *Academic Journal of Interdisciplinary Studies*, *11*(2), 155. doi:https://doi.org/10.36941/ajis-2022-0042

Sun, W., & Huang, C. (2022). Predictions of carbon emission intensity based on factor analysis and an improved extreme learning machine from the perspective of carbon emission efficiency. *Journal of Cleaner Production*, *338*. doi:https://doi.org/10.1016/j.jclepro.2022.130414

Wang, Y., Zhou, Y., Zhu, L., Zhang, F., & Zhang, Y. (2018). Influencing factors and decoupling elasticity of China's transportation carbon emissions. *Energies*, *11*(5). doi:https://doi.org/10.3390/en11051157

Yang, L., Xia, H., Zhang, X., & Yuan, S. (2018). What matters for carbon emissions in regional sectors? A China study of extended STIRPAT model. *Journal of Cleaner Production*, *180*, 595-602. doi:https://doi.org/10.1016/j.jclepro.2018.01.116

Yin, Y., Jiang, Z., Liu, Y., & Yu, Z. (2019). Factors affecting carbon emission trading price: Evidence from China. *Emerging Markets Finance and Trade*, *55*(15), 3433-3451. doi:https://doi.org/10.1080/1540496X.2019.1663166

Zhu, C., & Gao, D. (2019). A research on the factors influencing carbon emission of transportation industry in "the belt and road initiative" countries based on panel data. *Energies*, *12*(12). doi:https://doi.org/10.3390/en12122405