POPULATION AGING AND CARBON EMISSIONS: AN EMPIRICAL STUDY OF SHANGHAI AND GUANGZHOU USING REGRESSION ANALYSIS

BY

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AN INDEPENDENT STUDY SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS SOCIAL INNOVATION AND SUSTAINABILITY
SCHOOL OF GLOBAL STUDY
THAMMASAT UNIVERSITY
ACADEMIC YEAR 2023

THAMMASAT UNIVERSITY
THE SCHOOL OF GLOBAL STUDIOS

INDEPENDENT STUDY

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ENTITLED

POPULATION AGING AND CARBON EMISSIONS:
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was approved as a partial fulfillment of the requirements for
the degree of Master of Arts in Social Innovation and Sustainability

On December 3, 2023

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Independent Study Title	POPULATION AGING AND CARBON EMISSIONS: AN EMPIRICAL STUDY OF SHANGHAI AND GUANGZHOU USING REGRESSION ANALYSIS
Author	RUIJIE WANG
Degree	Master of Arts
Major Field/ Faculty/ University	Social Innovation and Sustainability The School of Global Study Thammasat University
Thesis Advisor	Neil Gains, Ph.D.
Academic Year	2023

ABSTRACT

From the current situation of demographic and industrial structure, China, as the largest CO2 emitter in the world, has an urgent need to reduce its emissions. Therefore, according to the demographic and consumption structure of China, the impact of carbon emissions on the independent variables was investigated using regression analysis based on the STIRPAT model. These findings indicate that, in Guangzhou, GDP growth and population aging have a favorable impact on CO2 emissions growth, whereas technology level has a somewhat negative impact. Shanghai's aging population, GDP, and technology level all have a positive effect on the growth of CO2 emissions. In the concluding section of this paper, different measures are considered for controlling carbon emissions in different regions, and the measures and policy recommendations combine the concepts of the "left-hand side strategy" and degrowth.

Therefore, this paper suggest that it would be more appropriate to directly control carbon emissions by taxing and regulating them. Taxation and control of carbon emissions are more effective, and the two-child policy is also suggested as an effective way of controlling carbon dioxide emissions.

Keywords: Population Aging, Carbon Emissions, Regional Differences, STIRPAT Models, Shanghai and Guangzhou

ACKNOWLEDGEMENTS

In the process of completing this thesis, I sincerely express my gratitude to those who have supported and assisted me on my academic journey.

Firstly, I would like to thank my supervisor and chairman, Dr. Neil Gains and Dr.Daniel McFarlane, for their guidance and meticulous instruction throughout the entire research process, enriching my academic experience.

I extend my gratitude to my families and friends for their selfless support and understanding during my academic and writing endeavors. Without their encouragement, I would not have been able to complete this thesis.

Finally, I appreciate all the literature cited in my research and the scholars from previous studies. Their work has laid a solid foundation for my research.

Here, I extend my heartfelt thanks to everyone who has supported, encouraged, and assisted me throughout this journey.

RUIJIE WANG

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CHAPTER 1
INTRODUCTION

1.1 Background

In today's fast-paced world, sustainable development has become a widely discussed topic. Many individuals are increasingly concerned with finding ways to strike a balance between promoting economic growth and supporting sustainable development. Among other things, one sector is paid attention by the public, which is the relationship between population aging and carbon emission.

With advancements in medical technology and improved living standards, life expectancy continues to rise, which makes the percentage of the elderly population increase. Secondly, the declining fertility rate and smaller family sizes are also some of the causes of population aging; furthermore, with the development of the social economy, people's work and retirement styles are also changing, which further accelerates the process of population aging. Concern over the effects of population aging on the environment is growing as the problem of global population aging continues to escalate. One of the main contributors to climate change, carbon emissions are now a major concern on the international environmental agenda. Because of human activities like burning fossil fuels, deforestation, and industrial processes, greenhouse gases like carbon dioxide, methane, and nitrous oxide are released into the atmosphere, raising Earth's temperature and causing catastrophic effects like extreme weather, rising sea levels, and a decline in biodiversity. As a result, carbon emissions have become a major concern, attracting the attention of governments, organizations, and individuals worldwide to take action towards reducing carbon emissions and mitigating their impact on the environment.

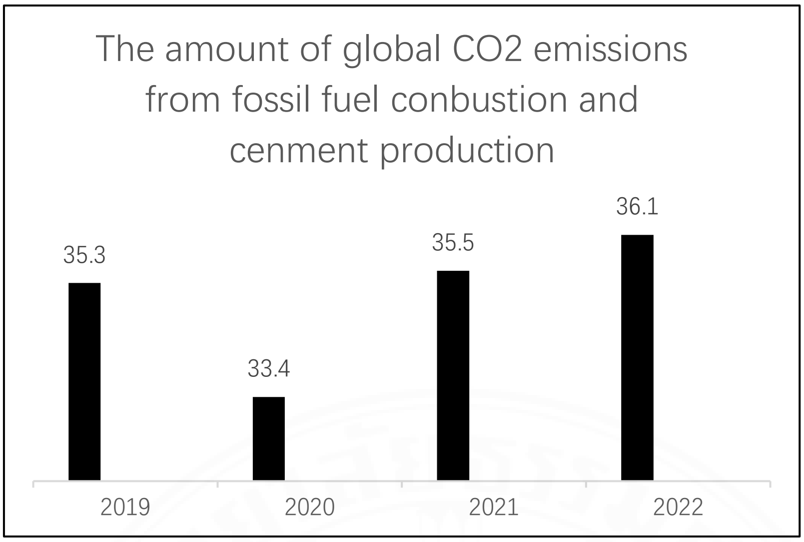

Figure 1.1: The amount of global CO2 emissions from fossil fuel consumption and cement production from 2019 to 2022. Source: International Energy Agency (2022)

Looking at Figure 1.1, We can see that global CO2 emissions from fossil fuel combustion and cement production amount to 36.1 GtCO2 in 2022.(1 Gt of CO2 = 1 billion tons of carbon dioxide). Compared to GtCO2 in 2019, 2020, and 2021, emissions in 2022 have increased by 2.0%, 7.9%, and 1.5%, respectively. In the wake of the COVID-19 pandemic, global CO2 emissions saw a sudden drop in 2020. However, recent changes indicate that emissions have surpassed the pre-pandemic levels, indicating a resurgence in the trend of sustained growth. This implies that the efforts to reduce carbon emissions must be intensified to combat the adverse effects of climate change. At the same time, population aging is a serious concern.

From Table 1.2, according to the World Bank, the percentage of the global population aged 65 and over increased year by year from 2000 to 2019 World Bank data also shows that population aging is more pronounced in developed countries, such as the United States at 16%, Japan at 28% and so on. Nevertheless, the level of aging is significantly lower in developing countries than in developed ones. For example, 11% in China, 6% in India, and 9% in Brazil. From these data, many countries are experiencing significant aging challenges, with their aging rate well above the global average. Many countries are experiencing significant aging challenges, with their aging rate well above the global average.

Year	Global Population Aged 65 and Over
2000	6.874%
2010	7.567%
2019	9.099%

Table 1.1: The percentage of the global population aged 65 and over
Source: United Nations (2019)

Year	United States	Japan	Germany	France	United Kingdom	Italy	Canada	China	India	Brazil
2019	16%	28%	22%	20%	19%	23%	18%	11%	6%	9%

Table 1.2: The percentage of the population aged 65 and over.
Source: United Nations (2019)

Because the aging population increases and the age structure changes dramatically, changes in the structural characteristics of society's production and consumption groups will trigger changes in economic development and energy consumption, which in turn will lead to changes in carbon emissions. In other words, population aging has complex implications for global CO2 emissions.

1.2 The situation of population aging and carbon emissions in China

The relationship between population aging and carbon emissions has been a topic of great interest, especially in highly industrialized and urbanized areas (Wang et al., 2016). China is typical of highly industrialized and urbanized regions and faces serious population aging problems. (Banister et al., 2012)The percentage of China's population aged 65 and overreached 13% in 2021, which is higher than the national average of 10% (World Bank Open Data, 2022.)With the accelerated industrialization and urbanization in China, China's carbon emissions are also increasing. China is one of the top carbon emission emitters. It accounts for 27.79% of global emissions. In 2018, it emitted 13,739.79 million tons. It has had one of the biggest increases in carbon emission emissions — 250% since 1990(UNEP, 2021). The power sector accounts for 48% of CO2 emissions from energy and industrial processes, while industry contributes 36%, followed by transport with 8%, and buildings with 5% (IEA,2021).

1.3 The situation of population aging and carbon emissions in Shanghai and Guangzhou

Shanghai and Guangzhou are two of China's most populous and influential cities. As major first-tier cities, they are both important economic centers and play significant roles in China's rapid development. Shanghai, located in eastern China, is known for its booming financial industry, modern infrastructure, and international trade. Guangzhou, located in southern China, is a vital transportation hub, with a thriving manufacturing industry and a rich cultural heritage. Both cities are not only important on a national scale but also have global significance. About Shanghai, as of 2021, about 17.4 percent of the population of Shanghai municipality in China were 65 years and older. This share is expected to grow in the coming decades (C. Textor, 2023). For Guangzhou, where 18 percent of the population is over the age of 65, by 2030, the proportion of elderly Chinese in need of care is expected to reach 30 percent of the population. (Huang, 2023).

Shanghai's annual carbon emissions are now 200 million tons. Of this, industry accounts for about 45 percent, buildings for about 25 percent, and transportation for about 30 percent. (Shi,2021).2010 Guangdong's overall energy consumption amounted to 272 million TCE(Tons of Coal Equivalent), accounting for 8.7% of the country's total energy consumption. The primary sources of energy consumption in the region include coal, crude oil, and electricity. However, Guangdong was confronted with significant challenges, primarily stemming from a domestic energy supply shortfall and heavy reliance on energy imports (Zhou et al., 2013).

1.4 Research questions and hypothesizes

Due to the Chinese government's population control policies (one-child policy), which differ from those of other countries, This is the primary cause of China's declining birth rate, according to this paper. Population aging will eventually result from this, increasing the share of elderly individuals in the population structure. Thus, the present study postulates that the aging of the population has a negative and substantial influence on carbon emissions, meaning that a rise in the share of the old population will result in lower carbon emissions. We also expect that because of the two cities' different economic and demographic traits, this link might be different in each of them. By providing answers to the following research questions, this study hopes to address the topic of the connection between population aging and carbon emissions:

1. What extent has population aging affected carbon emissions in Shanghai and Guangzhou during the period from 2014 to 2021?
2. How does the impact of this phenomenon differ between these two regions?

This study employs the extended STIRPAT model to conduct a comprehensive regression analysis, The STIRPAT model is an extension and improvement of the IPAT mode, The IPAT model identities do not easily accommodate non-monotonic or non-proportional effects arising from the driving forces. In order to address this limitation, researchers reformulated IPAT into a stochastic model, which is known as STIRPAT (Rosa & Dietz,1998). This study examines the intricate relationship between population aging and CO2 emissions in the urban contexts of Shanghai and Guangzhou from 2014 to 2021. Through this analytical approach, the research endeavors to shed light on the various factors influencing carbon emissions in these two cities and to provide insights into the implications of demographic changes on environmental sustainability. The study that follows is organized in the following manner: Chapter 2 presents the literature review. Chapter 3 introduces the research methodology and data sources. Chapter 4 describes the estimation method and the analysis of the results, and Chapter 5 gives the conclusions and policy recommendations.

CHAPTER 2
LITERATURE REVIEW

Yeongjun Yeo and Dongnyok Shim's (2015) studies of India and China have concluded that the main factors contributing to carbon emissions in these countries are population and energy consumption intensity.So this paper's classification of literature review will be divided into demographic structure and population aging, and also, under these classifications based on energy consumption and productivity to analyze. In addition to discussing other relevant topics, the article also delves into the theory of degrowth, which proposes a shift away from the traditional emphasis on economic growth and promotes a more sustainable, equitable, and efficient use of resources.

2.1 Demographic structure

2.1.1 Energy consumption

From this perspective, in many papers, demographic changes are noted as having a great impact on energy consumption and carbon dioxide CO2 emission. Research in this area has typically used two approaches:

a. the cross-sectional comparison approach compares data from different regions, countries or groups at the same point in time to explore the relationship between population ageing and carbon emissions.

Weidong and Li (2018) found that demographic structure has a U-shaped relationship with carbon emissions, middle-aged populations are associated with higher emissions, and both younger and older populations are associated with lower emissions. Regional variations are evident, with a notably positive correlation between population aging and carbon emissions observed in the eastern region. In contrast, during the period from 1999 to 2014, the central and western regions exhibited a negative association.

b. the Longitudinal study approach tracks energy consumption and carbon emissions data for the same region, country or group of people over a longer time horizon to understand the relationship between them.

Wang (2019) found that the increase in the proportion of the elderly population in China is associated with a reduction in carbon emissions from 1995 to 2030.

Yayun Yang, Tao Zhao, and Yanan Wang (2015) think the changes in population age structure have significantly positive impacts on carbon emissions in Beijing from 1984 to 2012.

Kalpana Regmi and Abdul Rehman (2021) analyzed Nepal from 1980-2016 and found that carbon emissions hurt population growth, energy use, and economic progress.

2.1.2 Production

From this perspective, for productivity, demographic changes can influence labor supply and technological innovation, For example, population aging can lead to a reduction in the workforce, which in turn can lead to lower levels of productivity. Therefore, from this perspective, concerning productivity, demographic changes can impact both labor supply and technological innovation. For instance, the aging of the population might result in a decrease in the workforce, subsequently leading to diminished productivity. Consequently, this decline in productivity could contribute to reduced carbon emissions. In another view, A decrease in available labor may lead to greater use of energy-intensive automated and mechanized production methods, resulting in significant carbon emissions. Similarly, technological innovation can play an important role in influencing productivity levels. Advances in automation, artificial intelligence, and other advanced technologies can help companies become more efficient and productive. However, they may also result in job losses. Similarly, this leads to automated and artificial intelligence replacing labor, The process is producing a considerable amount of carbon emissions. Research in this area has used two approaches:

a.The cross-sectional comparison approach

Li and Wang (2021) found that with the population aging and labor market conditions improving, the level of carbon emissions is likely to decrease.

b.The Longitudinal study approach

Yang and Wang (2010) also noted that as China's population ages, its carbon emissions tend to rise. The growth of the population, the rate of urbanization, the standard of living of inhabitants, the intensity of energy consumption, and the share of secondary industry's output value are all factors that are strongly linked to the rise in carbon emissions.

Taoyuan Wei and Qin Zhu (2018) find that the aging of the workforce over time may lead to a decline in economic growth while reducing CO2 emissions due to changes in consumption patterns and work behavior.

2.2 Population aging

2.2.1 Energy consumption

The problem of population ageing is intensifying, and the elderly population will have an increased need for social welfare and health care, which will lead to an increase in energy consumption. Conversely an increase in the proportion of older people will also reduce carbon emissions. This is because their need for transportation will decrease. Yan and Wang (2019) discovered that China's indirect household carbon emissions will continue to increase due to changes in household consumption patterns as the population ages. Zhang and Tan (2016) explored 29 provinces in China and found that population size and economic growth have a significant positive effect on carbon emissions, while population aging has a negative effect on carbon emissions.

2.2.2 Production

In terms of production, it has been observed that younger individuals often work in high-carbon industries such as manufacturing and construction, whereas older individuals tend to work in low-carbon industries like service-based work. Moreover, younger people have a tendency to follow trends and fashions. Which can lead to overconsumption and waste, consequently contributing to increased carbon emissions.

Yang Yu and Yuru Deng (2018) discover population aging, industrial patterns and per capital wealth are found to increase, and then there is an increase in carbon dioxide CO2 emission. And a decrease in energy intensity has an increase in carbon dioxide CO2 emission.

2.3 Degrowth

In another view, Alcott (2010) proposed an alternative approach, which he called "left-hand side strategies", inspired by the I = PAT equation originally developed by Schneider and others.These strategies aim to limit the impact on the environment by setting caps or restrictions, rather than directly addressing the factors that contribute to the problem. It is important to note that reducing these factors may cause the other two components to increase or rebound. Left-hand side strategies include policies such as resource rationing, capping, or taxing resource use. Alcott argues that cap and ration policies have clear effectiveness in achieving environmental goals and that they offer simplicity and clarity of approach compared to complex multifaceted interventions targeting consumption, population dynamics, or technology-driven strategies. Alcott's points are consistent with or related to the concept of "degrowth", which advocates slowing economic growth and reducing consumption and resource use to achieve environmental sustainability and social equity (Schneider et al., 2010) .

2.4 Conclusion

Current studies mainly focus on changes in lifestyle and energy consumption, which represent two different types of relationships: positive and negative.

Some papers concluded positive correlations, which indicate a positive relationship between demographic factors and carbon emissions, an increase in demographic factors leads to an increase in carbon emissions. And the paper with negative correlation. then indicate that there is a negative relationship between demographic factors and carbon emissions, an increase in demographic factors will instead lead to a decrease in carbon emissions.

Many studies have concluded that there is a negative correlation between aging populations and carbon emissions in different countries, which is largely due to different lifestyles, such as transportation modes. However, most articles tend to discuss the impact of energy consumption on aging populations. There are also different angles from which to approach this topic. Blake Alcott (2010) offers new perspectives on policy recommendations in the wake of population aging, bringing new insights into policies to control population aging or consumption patterns. Alcott highlights the rebound effect, whereby attempts to reduce development in areas such as population aging or consumption can lead to counterproductive results.

At the moment, many studies focus on analyzing a single country or region, with little consideration of regional differences. Given the differences in economy, culture, society, and environment across different countries or regions, there may be significant variations in the correlation between demographic composition and carbon emissions. Therefore, this paper suggests that a more comprehensive investigation is necessary for various regions. It is also possible to compare the relationship between demographics and carbon emissions in two countries or two regions, which can reveal similarities and differences between different countries.

Additionally, when conducting research, researchers tend to focus on how the demographic composition directly influences carbon emissions, ignoring other related factors such as technological level and policy changes. For example, studies those two relationship under population policies, are of some importance both for the development of population policies and for combating climate change. Therefore, in the future, researchers may consider introducing other relevant factors.

CHAPTER 3
METHODOLOGY AND DATA

3.1 Research Design

This study used a quantitative research approach to compare and measure the relationship between population aging and carbon emissions in Shanghai and Guangzhou. It involves extracting quantitative results from extensive datasets. Furthermore, quantitative analysis allows for a deeper exploration of this relationship, providing policymakers with more reliable data support. Given the significant impact of carbon emissions on the global environment. Accurate data is essential to assess severity and propose solutions for sustainable development. Additionally, by comparing research findings, we can summarize the differences in data between these two Chinese cities. Therefore, the quantitative research method is optimal for achieving these objectives.

The STIRPAT model serves as the theoretical framework for this study, integrating regression analysis into the research approach. This model is an extension and improvement of the IPAT model. The IPAT model is used to examine the impact of three factors, which are population, affluence, and technology, and the impact on environmental effects (DeHart & Soulé, 2000). The form of the IPAT model is Impact = Population x Affluence x Technology

The STIRPAT model builds upon the IPAT model by introducing more specific factors to assess the contributions of these three factors to environmental impacts. The STIRPAT model considers a broader range of social, economic, and technological variables, For example, population, population structure, economic level, energy consumption, GDP, urbanization, technology level, international trade, culture and value, policy measure, geographical factors, and more.

The IPAT model has a significant advantage due to its foundation in ecological principles. Clear and concise specifications, and its ability to explain how changes in driving factors impact the environment. However, it has some key limitations. The IPAT model is essentially an accounting equation (a mathematical identity), which does not allow for hypothesis testing. Additionally, it presupposes proportionality in the relationships between factors. To advance sociological theory, it is essential to empirically test hypothesis about the relationship between anthropogenic factors and impacts instead of assuming them within the model's structure.

In contrast to the IPAT model, the STIRPAT model is not an accounting equation; it is a stochastic model that can be employed for empirical hypothesis testing. While the IPAT model is a mathematical identity. primarily used to assess the potential impact of driving forces, Consequently, the STIRPAT model is a stochastic model that supports hypothesis testing. As a result, The STIRPAT model provides more flexible tools for exploring the connections between driving forces and the environment. Additionally, the STIRPAT model can explore non-linear relationships and relationships over three variables.The population aging rate as the demographic variable in the analysis framework. At the same time, in environmental research, the relationships between many factors can be nonlinear. To address the distribution characteristics of the data and reduce the nonlinear relationships between variables. Before data analysis,This study taking the logarithm for the STIRPAT model. This transformation can linear certain nonlinear relationships, making it easier to estimate the regression model. The analysis framework used in this study can be expressed as follows:

equation (1): $\ln I=\alpha+\ln\beta_1 P+\ln\beta_2 A+\ln\beta_3 T+\varepsilon$

Where:

I stand for CO2 emissions

P represents the degree of population aging defined as the population over 60 years of age ratio to the total population

A is per-capita GDP (Gross Domestic Product)

T denotes the technology level represented by energy intensity, defined as the amount of energy consumed for every unit of economic output.

ε is an error term and α is a constant.

β_1,β_2,β_3, and β_4 correspond to the coefficient of each driving factor.

3.2 Data collection

The population, aging of the population, GDP per capita, energy consumption, population aging ratio, and tertiary industry ratio for the years 2014–2021 are included in the data sample of this article. Data on energy consumption, population, number of people over 60, per-capita GDP, and CO2 emissions in Shanghai and Guangzhou are taken from the Statistical Yearbook, which is issued separately by the Guangzhou Bureau Statistics (GBSC,2022) and the Shanghai Bureau Statistics (SBSC, 2022). The tertiary industry ratio and population aging ratio data were computed. Where, the population aging ratio is population aging size divided by population size. The tertiary industry ratio is determined by calculating the amount of energy consumption, which includes both Industrial Energy Intensity per Gross Domestic Product and Industrial Electricity Intensity per Gross Domestic Product, and then dividing this by the Gross Domestic Product (GDP). This ratio serves as a measure to assess the energy consumption patterns within the tertiary industry relative to the overall economic output.

In addition, according to the Intergovernmental Panel on Climate Change guidelines (2008), the CO_2 Emission factor for standard coal is 2.7725 tc/tsce (tons of carbon dioxide per ton of standard coal equivalent), and the Shanghai Statistical Yearbook was used as the basis for gathering the overall quantity of energy consumed (Table 3.1). Guangzhou information taken from Table 3.2 of the Guangzhou Statistical Yearbook. One kWh is equal to 0.1229 kg of standard coal equivalent (SCE), which is a unit of energy measurement given in terms of the mass of coal. Based on existing data, the entire energy consumption is converted to its SCE equivalent value to determine the total CO2 emissions.In this case, the total energy consumption is multiplied by 2.7725 to determine the carbon dioxide (CO2) emissions.

Year	Population aging ratio (%)	Per capita GDP (CNY)	Tertiary industr y ratio	Total energy consumption (104 tsce)	CO2 Emission (104 tons)
2014	28.77%	25269.75	42.11%	10639.86	29599
2015	30.21%	26887.02	40.65%	10930.52	30305
2016	31.57%	29887.02	37.61%	11241.73	31168
2017	33.10%	32925.01	34.57%	11381.85	31556
2018	34.33%	36011.82	31.81%	11453.73	31755
2019	35.16%	37987.55	30.79%	11696.59	32428
2020	36.08%	38963.3	28.49%	11099.59	30774
2021	36.28%	43213.85	28.03%	11683.02	32391

Table 3.1: Data for each variable in Shanghai.
Source: Shanghai Statistical Yearbook(2022).

Year	Population aging ratio (%)	Per capita GDP (CNY)	Tertiary industr y ratio	Total energy consumption (10^4 tsce)	CO_2 Emission (10^4 tons)
2014	16.69%	16135.95	34.10%	5496.46	15238
2015	17.27%	17347.37	32.80%	5688.89	15772
2016	17.76%	18559.73	31.50%	5852.60	16226
2017	18.02%	19871.66	30.00%	5961.97	16529
2018	18.25%	21002.14	29.20%	6128.55	16991
2019	18.40%	23844.69	26.40%	6294.20	17450
2020	18.27%	25068.74	24.70%	6191.49	17165
2021	18.27%	28231.96	23.30%	6575.64	18230

Table 3.2: Data for each variable in Guangzhou.
Source: Guangzhou Statistical Yearbook.(2022).

3.3 Limitations

1.Limitations of this study include the fact that the timeframe of the data only covers the period from 2014 to 2021. This time frame may not fully reflect the long-term trend of carbon emissions and the relationship between the independent and dependent variables.

2.Another limitation relates to the regional scope of the study, especially the comparison between Guangzhou and Shanghai. It is worth noting that these two cities are not representative of all cities in China. China is geographically diverse, with different regions having different industrial structures, economic conditions and demographics. Therefore, the findings of these two cities may not be directly applicable to the whole country.

3.There are also considerations related to incomplete modeling. the STIRPAT model typically focuses on a variety of socio-economic factors, but it cannot take into account all the potential influences. Factors such as urban planning, government policies, or socio-cultural factors may also affect carbon emissions, which are not fully considered in the model.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Data Analysis

From Figure 4.1.1, in the CO2 emissions of Guangzhou and Shanghai, we can observe a continuous increase from 2014 to 2019. However, there was decrease trend in 2020, which can be caused by the COVID-19 pandemic. During 2020, China implemented epidemic prevention policies that resulted in an economic lockdown, leading to reduced energy consumption and a subsequent decline in carbon emissions.

From Table 3.1 and Table 3.2, turning to the population aging ratio, we see that in Guangzhou, the ratio increased from 2014 to 2019, but in 2020 and 2021, it declined. This fundamental shift can be caused by the COVID-19 pandemic, which caused a substantial number of elderly individuals to pass away, resulting in a decreased proportion of elderly people in the population. In contrast, Shanghai remained unaffected. The primary reason for the differing impact is the contrasting aging trends between Guangzhou and Shanghai. From the data of Shanghai, we saw an increase in its aging population ratio, unaffected by the pandemic. In contrast, Guangzhou experienced a decline in the aging population ratio due to variations in population migration. As one of China's economic hubs, Shanghai attracted a considerable number of young individuals and migrants for work and living, which helped maintain a stable aging population ratio. In contrast, Guangzhou attracted fewer migrants and had a higher proportion of elderly residents, making it more severely impacted. In terms of GDP, both Shanghai and Guangzhou experienced continuous growth. However, carbon emissions decreased. According to the pandemic assessment report, the pandemic had a short-term impact on industrial production.

The results of the pandemic assessment indicate that in 2020, the value-added by large-scale industries in China increased by 2.8% compared to the previous year, marking a nearly 50% decrease in growth rate. The automobile manufacturing industry was the most severely affected, with a 50% decline in production in March. The Ecological Environment Department's environmental planning institute reported a nearly 30% decrease in the cement industry on two occasions on December 27, 2021. The most significant impact was observed in activities of different industries, with effects ranging from 20% to 50% before April.

During the pandemic, some high-carbon emission industries and sectors faced restrictions, while low-carbon consumption sectors, such as green technology and internet services, continued to thrive. This shift in industry structure can explain the decrease in carbon emissions and the simultaneous growth in GDP. Additionally, progress was made in the green and low-carbon transformation of sectors.

The pandemic did not slow down the increase in renewable energy generation capacity. Despite initial disruptions in the supply chain in early 2020, China continued to make significant strides in wind and solar energy capacity installation. (Mastoi et al., 2022)

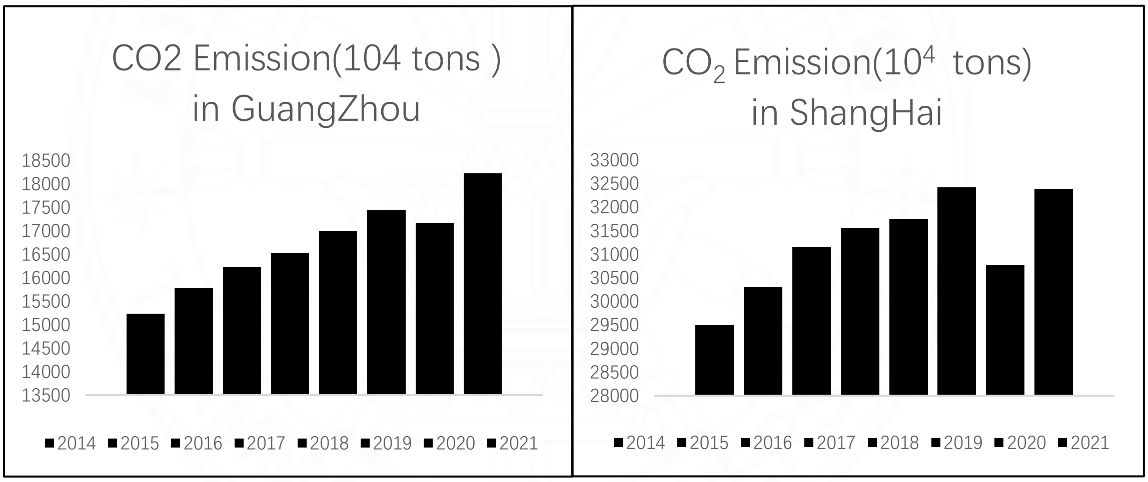

Figure 4.1: CO_2 Emission in Guangzhou and Shanghai
Calculation of variable sources: Guangzhou Statistical Yearbook (2022), Shanghai Statistical Yearbook (2022).

4.2 Regression Results

This essay addresses several variables and emphasizes that covariance can lead to significant issues. In a regression model, covariance is a statistical phenomenon that characterizes a high level of correlation between more than two variables. As a result, this study first analyzed equation (1) using OLS (ordinary least squares) regression and then ran an autocorrelation test on the variables, the results of which are displayed in Tables 4.2.1 and 4.2.2.

The Shanghai OLS results show Log_T and Log_A have highly significant coefficient estimates ($p < 0.001$), while the coefficient estimate for Log_P is marginally significant at a significance level of $\alpha = 0.05$ ($0.05 < p < 0.1$). The Multiple R-squared is 0.9998, which is very close to 1, indicating an excellent fit of the model. The Adjusted R-squared is 0.9997, also very close to 1, therefore, the model explains the variance in the target variable exceptionally well. The F-statistic has a very large value (8186), and the corresponding p-value is extremely small (4.972e-08), demonstrating the model's overall significance. In summary, this regression model exhibits a very high degree of fit. The model demonstrates high overall significance. The Guangzhou OLS results show the coefficient estimates for Log_T2 and Log_A2 are highly significant ($p < 0.001$), while the coefficient estimate for Log_P2 is not significant at the 0.05 significance level ($0.05 < p < 0.1$). The situation is similar to the Shanghai model. The Multiple R-squared is 0.9999, indicating a higher level of model fit compared to the Shanghai model. The Adjusted R-squared is also 0.9999, very close to 1, implying that the model exceptionally explains the variance in the target variable. The F-statistic has a very large value (1.787e+04), and the corresponding p-value is extremely small (1.043e-08), demonstrating the model's high overall significance.

In conclusion, the regression models for both Shanghai and Guangzhou possess extremely high levels of fit, with both Log_T and Log_A having a significant effect on Log_CO2emission, while Log_P is not very significant. The overall significance level of the model is also very high.

The least squares analysis of equation (1) in Shanghai reveals that each variable's coefficients have extremely large variance inflation factors (VIF). which may indicate stronger covariance between them. In Table 4.2.2, Although the VIF of Log_P2 is small, it indicates that it has less effect on covariance with other independent variables. However, Log_T2 and Log_A2 have a larger VIF, which may indicate a stronger covariance between them.

Coefficients:	Estimate value	Std.error	T value	P value	VIF
Intercept	0.77357	0.12482	6.197	0.00345	
Lop_P	-0.04410	0.01635	-2.698	0.05422	44.5777
Log_T	0.99677	0.01133	87.992	1.00e-07	78.2505
Log_A	0.01861	0.01174	86.761	1.06e-07	112.5558
Residual standard error:0.000553 on 4 degrees of freedom Multiple R-squared:0.9998 Adjusted R-squared:0.9997 F-statistic：8186 on 3 and 4 Degrees of freedom P-value:4.972e-08					

Table 4.1 Ordinary least square estimation and VIF value for Shanghai

Coefficients:	Estimate value	Std.error	T value	P value	VIF
Intercept	1.17748	0.18293	6.437	0.003	
Lop_P2	0.02609	0.01820	1.434	0.225	6.131933
Log_T2	0.98704	0.02414	40.882	2.14e-06	176.661458
Log_A2	0.98702	0.01898	51.994	8.19e-07	215.433075
Residual standard error:0.000553 on 4 degrees of freedom Multiple R-squared:0.9998 Adjusted R-squared:0.9997 F-statistic：8186 on 3 and 4 Degrees of freedom P-value:4.972e-08					

Table 4.2 Ordinary least square estimation and VIF value for Guangzhou

4.3 Tests for Multicollinearity

From the value of VIF, Shanghai’s and Guangzhou’s VIF is greater than 10, except for the population aging ratio of Guangzhou. It indicates a severe multicollinearity issue, with a high degree of correlation among the model's independent variables. This can potentially lead to unstable estimates and difficulties in interpretation.

In this point, if OLS regression analysis is used, the model's conclusions may be different from the actual situation. Therefore, this paper used the ridge regression method in this study.

4.4 Ridge Regression Analysis

The ridge regression equation of Shanghai expressed as follows:
Log_CO_2 emission = 9.508 + 0.077 * Log_P + 0.009 * Log_T + 0.089 * Log_A

The variables of population aging, per capita GDP, and technological level show a positive link with the rise in CO2 emissions, according to the regression equation recorded in Shanghai. Consequently, these independent variables exert a constructive influence on the escalation of CO2 emissions within the timeframe of 2004-2021. The coefficients assigned to each variable within the equation signify the extent of their impact. To elaborate, the elasticity coefficient related to population aging is recorded at 0.077, indicating that a 1% rise in the aging population corresponds to a 0.077% increase in carbon emissions. According to the assumptions of this thesis, this result is directly opposite to our assumptions. The elasticity coefficient of GDP per capita is 0.089, indicating that when the GDP per capita increases by 1%, the carbon emission increases by 0.089%.The elasticity coefficient of the technology level is 0.009, indicating that when the technology level increases by 1%, the carbon emission increases by 0.009%.

The ridge regression equation of Guangzhou expressed as follows:
Log_CO2 emission2= 9.434 + 0.531 * Log_P2 -0.117 * Log_T2 + 0.106 * Log_A2

Derived from the regression expression in Guangzhou, both population aging and GDP per capita exhibit a favorable correlation with the rise in CO2 emissions. In contrast, the technology level appears to impede the increase in CO2 emissions. The coefficients assigned to each variable within the equation elucidate the magnitude of their respective influences. Notably, the elasticity coefficient linked to population aging is calculated at 0.531, signifying that a 1% augmentation in the aging population corresponds to a 0.531% upsurge in carbon emissions. Intriguingly, this outcome directly contradicts our initial assumptions. Furthermore, the elasticity coefficient associated with GDP per capita is determined to be 0.106, indicating that a 1% increase in GDP per capita aligns with a 0.106% increase in carbon emissions. The elasticity coefficient of the technology level is 0.117, indicating that when the technology level increase by 1%, the carbon emission decrease by 0.117%.

4.5 Data Conclusion

Comparing the results of the two cities, it is clear that population aging has a stronger impact on carbon emissions in Guangzhou (with an elasticity coefficient of 0.531) than in Shanghai (with an elasticity coefficient of 0.077). This means that in Guangzhou, when the aging population rate increases by 1%, CO2 emissions increase by 0.531%, while in Shanghai, the same increase leads to only a 0.077% increase in emissions. This result suggests that CO2 emissions in Guangzhou are more sensitive to population aging, while emissions in Shanghai are less responsive to changes in population aging. This may reflect the different socio-economic structures, industrial characteristics, and possible policy differences between the two cities.

Based on the analysis findings, the technological advancement in Shanghai correlates positively with carbon emissions, while in Guangzhou, the level of technology is inversely related to carbon emissions.The formula of this study for the technology level, the technology level is equal to the energy consumption divided by the GDP, so the technology level and energy consumption is positively proportional to the relationship , which can be obtained, Guangzhou's energy consumption rose, but the carbon emissions have been reduced. The opposite is true for Shanghai, where energy consumption is rising and carbon emissions are also rising. Comparing the data for these two cities, this paper concludes that Guangzhou has more green technologies that optimize carbon emissions from energy consumption, while Shanghai has a much smaller role in green technologies. Shanghai's carbon reduction technologies and clean energy still have significant shortcomings, mainly in two areas.

1. Shanghai's clean energy substitution and energy-saving renovation efforts are insufficient, and technology for carbon reduction is not enough. The pace of breakthroughs and promotion of green technologies in Shanghai is relatively slow. First, in the industrial sector, carbon reduction technologies are still at research and development stage. For example, the application of technologies such as hydrogen

smelting in the iron and steel industry is still at the research and development stage. Second, in the transportation sector, the replacement of green travel modes still faces some difficulties. At present, the overall proportion of new energy vehicles is still less than 10%. In water transportation, the commercial application of hydrogen fuel cells on ships still faces difficulties in hydrogen extraction and storage. In civil aviation, the sustainable aviation fuel industry is still in its infancy.

2. Shanghai faces multiple challenges in promoting the transformation of its energy consumption structure. The scale development of local renewable energy is constrained by both site and cost. Shanghai's natural resource conditions for wind and photovoltaic energy are among the nation's four and three types of areas, respectively, while the scarcity of site resources and high development costs limit the development potential of local renewable energy (Wang, 2022).

Guangzhou has greater potential for green technology. As an economically developed but relatively energy-poor region, Guangzhou has taken the lead in laying out the development of the hydrogen industry, releasing the Hydrogen Industry Development Plan, and vigorously promoting the development of the hydrogen industry. Meanwhile, Guangzhou has a large potential for green transportation. With the further promotion of electrification, the gradual and extensive use of hydrogen energy, and the shift of highway bulk cargo transportation to railroads and waterways, Guangzhou has also contributed to the reduction of carbon emissions through the development of green transportation (Guangzhou Bureau of Statistics,2023).

From the results of these analyses, it appears that these data are consistent with the findings of several previous studies (Yang & Wang, 2020; Zhang & Tan, 2016; Li et al., 2018). At the same time, there are conclusions to the contrary (Menz & Welsch, 2012). These studies also provide explanations for the gradual increase in the consumption demand of the elderly because of the gradual decline in the body's health functions. According to the China Silver Industry Development Report (2014), from 2014 to 2050, with stable economic growth and the gradual improvement of the social pension insurance system, the senior population's capacity for consumption will rise from $4 trillion to $106 trillion. and its share of GDP will rise from 25% to 33% (CHINA REPORT OF THE DEVELOPMENT ON SILIVER INDUSTRY,2014). It is expected that with the aging of the population and the rapid development of urbanization, the consumption ratio of the elderly in China will increase greatly. On the one hand, the more serious the aging of the population is, the more the elder's demand for medical needs and healthcare services will gradually increase.

According to York (2007) the elderly population's demand for energy-intensive products such as heating, transportation, and electricity is significantly higher than that of other age groups.

Alternatively, according to traditional Chinese concepts, Chinese people have the habit of saving large amounts of money or using it to buy houses and cars.In the future, as urbanization accelerates, there will be an increase in the number of households with two or more homes, which will further increase carbon emissions. These factors are influencing the growth of consumption demand among the elderly, which in turn has a positive impact on carbon emissions.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Regional Variability and Policy Directions

This study examines the impacts of population aging, GDP, and technology level on carbon emissions in Shanghai and Guangzhou from 2014 to 2021. Through the regression analysis of the STIRPAT model, we confirm the positive correlation between population aging and CO2 emissions in Guangzhou and Shanghai. This provides important clues for the formulation of environmental policies. On this basis, we consider the concept of "degrowth" and Alcott's "left-hand side strategy". The left-hand side strategy is a simpler and clearer policy than complex interventions targeting consumption, demographic dynamics, GDP, or industrial structure, which only control carbon emissions.

Returning to the data. Although both studies demonstrate a great correlation between the aging and carbon emissions in Shanghai and Guangzhou. However, Guangzhou's total population size is small relative to Shanghai's total population. In the regression results, the impact of population aging on carbon emissions seems to be higher in Guangzhou than in Shanghai. This reflects the different demographic and urban characteristics between regions. This also means that when formulating policies for carbon emission control, it is necessary to consider the specific conditions of different regions, making the policies more targeted to achieve more effective environmental conservation goals. This regionalized policy direction will better target the carbon emission challenges in different regions with more specific and effective solutions.

Therefore, this paper provides some directions for controlling policies on carbon emission issues, combining the 'left-hand side strategy' and regional variability of carbon emissions.

5.2 Specific Policy Recommendations

This paper suggests that the government could adopt more refined measures, especially for Guangzhou, to strengthen the control measures on carbon emissions. Resource limitation strategies such as resource rationing or environmental taxes can be considered. These policies can reduce carbon emissions to a certain extent, These strategies are in line with the concept of 'degrowth'. However, a wide range of policies are needed to solve such a complex problem, and 'degrowth' may be only one of them". This study investigates the development of population aging and GDP in China and makes the following recommendations:

5.2.1 Suggested Optimization of the Implementation of the Two Child Policy.

The entire regression analysis's findings indicate that population aging has a significant influence on carbon emissions. According to Shanghai's regression analysis data, GDP has the most impact (0.089), followed by population aging (0.077). According to Guangzhou's regression statistics, GDP (0.106) is the second most important factor, behind population aging (0.531). Therefore, it is clear from the Guangzhou and Shanghai data that aging has a greater influence on carbon emissions. The influence on carbon emissions increases with the degree of the aging population. China faces the growing challenge of aging, which is exacerbated by the inadequacy of its pension system. One strategy to address this problem is for the government to promote the diversification of the pension industry and rapidly improve the overall pension system.

Simultaneously, the complete enforcement of the two-child policy can mitigate the acceleration of aging. Furthermore, there is a chance that the two-child policy will lead to changes in the job market and in the demographics. The opening of the two-child policy will lead to an increase in the number of births in China, which will greatly increase the proportion of the adult labor force in the total population over a certain period of time, and as this population gradually enters the labor market, it will increase the supply of the coming labor force. This has slowed down the trend of labor force decline in China. With regard to the age structure of the population, the overall population structure of China will be younger in the future because of the increase in the proportion of adult population in the total population. By prompting an increase in fertility, the two-child policy is expected to offset the trend of population aging to some extent. As more families choose to have a second child, the relative proportion of the younger population is likely to increase, thus balancing to some extent the growth of the older population.

In short, the two-child policy can bring about a balance between the total population and its structure, as well as a balance between the population and the level of economic and social development. These changes can alter the impact of ageing on carbon emissions, affecting both production and consumption.

5.2.2 Carbon emission tax and restriction.

From the results of regression analysis, Shanghai's GDP has a greater impact on carbon emissions than population aging, so in considering the concept of 'degrowth', we adopt Alcott's' left-hand side strategy 'to limit carbon emissions in terms of GDP. In terms of enforcing a carbon tax, Shanghai could consider establishing different tax rates for different industries to ensure that high-emitting industries face higher tax burdens, which could reduce emissions and incentivize industry transformation through taxation. So a mandatory carbon tax may be more applicable, which would effectively reduce the release of carbon from high-emission sources. At the same time, Shanghai could encourage green technology innovation. The government could establish funding programs to support startups and SMEs in developing environmentally friendly technologies to improve sustainable energy usage. So in terms of policy recommendations for Shanghai, the government should focus more on incentivizing companies to innovate with green technologies, while implementing a strict carbon tax system for high-emission industries.

From the data of Guangzhou, the impact of the aging population in Guangzhou is greater than the GDP, In order to lessen the impact on the demographic structure, the government should support the implementation of the two-child policy. The government should focus more on environmental protection initiatives for the senior citizenry at the same time. This can directly reduce the impact of the elderly on the environment by supporting programs such as waste classification, resource recycling, and environmental advocacy. On the other hand. The use of renewable energy should be encouraged to reduce the dependence on high carbon emissions. These policy recommendations are intended to be more targeted to address inter-regional differences, particularly the impact of aging on carbon emissions. Implementation of the recommended policies will require further adaptation and planning based on specific regional circumstances and actual policy needs.

5.3 Research Recommendations

Expanding the timeframe of the study: In order to more fully understand the long-term trends in carbon emissions and the relationship between the independent and dependent variables, this paper suggests expanding the timeframe of the study to a longer historical period. Consideration could be given to including earlier years or taking the study into the future to capture possible trends and changes.

Expanding the geographic scope of the study: In order to improve the external validity of the study, this paper suggests expanding the geographic scope of the study to cover more cities, especially those that represent different geographic regions, industrial structures and economic conditions in China. This would make the results more generalizable beyond Guangzhou and Shanghai.

In-depth study of the differences between different cities. This paper suggests a more in-depth analysis to understand the root causes of these differences. in order to reveal the special circumstances and trends among different cities.

REFERENCES

Book

Banister, J., Bloom, D. E., & Rosenberg, L. (2012). Population Aging and Economic Growth in China. In M. Aoki & J. Wu (Eds.), The Chinese Economy: A New Transition (pp. 114–149). Palgrave Macmillan UK. https://doi.org/10.1057/97811370342987

IPCC. (2008).2006 IPCC guide guidelines for national greenhouse gas inventories. https://www.ipcc-nggip.iges.or.jp/support/Primer_2006GLs.pdf

Wu,Tong. (2014)China Report of the Development on Silver Industry -2014. Beijing: Social Sciences Academic Press. ISBN: 978-7-5097-6281-3

Articles

DeHart, J. L., & Soulé, P. T. (2000). Does I = PAT Work in Local Places? The Professional Geographer, 52(1), 1–10. https://doi.org/10.1111/0033-0124.00200

Dietz, T., & Rosa, E. A. (1997). Effects of population and affluence on CO 2 emissions. Proceedings of the National Academy of Sciences, 94(1), 175–179. https://doi.org/10.1073/pnas.94.1.175

Li, W., Qi, X., & Zhao, X. (2018). Impact of Population Aging on Carbon Emission in China: A Panel Data Analysis. Sustainability, 10(7), Article 7. https://doi.org/10.3390/su10072458

Mastoi, M. S., Munir, H. M., Zhuang, S., Hassan, M., Usman, M., Alahmadi, A., & Alamri, B. (2022). A Critical Analysis of the Impact of Pandemic on China's Electricity Usage Patterns and the Global Development of Renewable Energy. International Journal of Environmental Research and Public Health, 19(8), 4608. https://doi.org/10.3390/ijerph19084608

Menz, T., & Welsch, H. (2012). Population aging and carbon emissions in OECD countries: Accounting for life-cycle and cohort effects. Energy Economics, 34(3), 842–849. https://doi.org/10.1016/j.eneco.2011.07.016

Pan, C., Wang, H., Guo, H., & Pan, H. (2021). How Do the Population Structure Changes of China Affect Carbon Emissions? An Empirical Study Based on Ridge Regression Analysis. Sustainability, 13(6), 3319. https://doi.org/10.3390/su13063319

Regmi, K., & Rehman, A. (2021). Do carbon emissions impact Nepal's population growth, energy utilization, and economic progress? Evidence from long- and short-run analyses. Environmental Science and Pollution Research, 28(39), 55465–55475. https://doi.org/10.1007/s11356-021-14546-6

Rosa, E. A., & Dietz, T. (1998). Climate Change and Society: Speculation, Construction and Scientific Investigation. International Sociology, 13(4), 421–455. https://doi.org/10.1177/026858098013004002

Schneider, F., Kallis, G., & Martinez-Alier, J. (2010). Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. Journal of Cleaner Production, 18(6), 511–518. https://doi.org/10.1016/j.jclepro.2010.01.014

Shi, A. (2003). The impact of population pressure on global carbon dioxide emissions, 1975–1996: Evidence from pooled cross-country data. Ecological Economics, 44(1), 29–42. https://doi.org/10.1016/S0921-8009(02)00223-9

Wang, D., (2022). Significant Issues and Proposed Strategies for Achieving Carbon Peak in Shanghai. Science Development, 0(6), 93-100. https://doi.org/10.3390/su13063319

Wang, Q., & Li, L. (2021). The effects of population aging, life expectancy, unemployment rate, population density, per capita GDP, urbanization on per capita carbon emissions. Sustainable Production and Consumption, 28, 760–774. https://doi.org/10.1016/j.spc.2021.06.029

Wang, Q., Wu, S., Zeng, Y., & Wu, B. (2016). Exploring the relationship between urbanization, energy consumption, and CO2 emissions in different provinces of China. Renewable and Sustainable Energy Reviews, 54, 1563–1579. https://doi.org/10.1016/j.rser.2015.10.090

Wei, T., Zhu, Q., & Glomsrød, S. (2018). Ageing Impact on the Economy and Emissions in China: A Global Computable General Equilibrium Analysis. Energies, 11(4), 817. https://doi.org/10.3390/en11040817

Xia, Y., Wang, H., & Liu, W. (2019). The indirect carbon emission from household consumption in China between 1995–2009 and 2010–2030: A decomposition and prediction analysis. Computers & Industrial Engineering, 128, 264–276. https://doi.org/10.1016/j.cie.2018.12.031

Yang, T., & Wang, Q. (2020). The nonlinear effect of population aging on carbon emission-Empirical analysis of ten selected provinces in China. Science of The Total Environment, 740, 140057. https://doi.org/10.1016/j.scitotenv.2020.140057

Yang, Y., Zhao, T., Wang, Y., & Shi, Z. (2015). Research on impacts of population-related factors on carbon emissions in Beijing from 1984 to 2012. Environmental Impact Assessment Review, 55, 45–53. https://doi.org/10.1016/j.eiar.2015.06.007

Yeo, Y., Shim, D., Lee, J.-D., & Altmann, J. (2015). Driving Forces of CO2 Emissions in Emerging Countries: LMDI Decomposition Analysis on China and India's Residential Sector. Sustainability, 7(12), Article 12. https://doi.org/10.3390/su71215805

York, R. (2007). Demographic trends and energy consumption in European Union Nations, 1960–2025. Social Science Research, 36(3), 855–872. https://doi.org/10.1016/j.ssresearch.2006.06.007

York, R., Rosa, E. A., & Dietz, T. (2003). A rift in modernity? Assessing the anthropogenic sources of global climate change with the STIRPAT model. International Journal of Sociology and Social Policy, 23(10), 31–51. https://doi.org/10.1108/01443330310790291

Yu, Y., Deng, Y., & Chen, F. (2018). Impact of population aging and industrial structure on CO2 emissions and emissions trend prediction in China. Atmospheric Pollution Research, 9(3), 446–454. https://doi.org/10.1016/j.apr.2017.11.008

Zhang, C., & Tan, Z. (2016). The relationships between population factors and China's carbon emissions: Does population aging matter? Renewable and Sustainable Energy Reviews, 65, 1018–1025. https://doi.org/10.1016/j.rser.2016.06.083

Zhou, D., Zhao, D., Liu, Q., Li, X.-C., Li, J., Gibbons, J., & Liang, X. (2013). The GDCCSR Project Promoting Regional CCS-Readiness in the Guangdong Province, South China. Energy Procedia, 37, 7622–7632. https://doi.org/10.1016/j.egypro.2013.06.708

Electronic Media

C. Textor.(2023). Age distribution of the population in Shanghai, China 2015-2022. Statistics. https://www.statista.com/statistics/1130402/china-shanghai-population-distribution-by-broad-age-group/

Guangzhou Bureau of Statistics(2023). http://tjj.gz.gov.cn/stats_newtjyw/sjjd/content/post_8762986.html

Guangzhou Statistical Yearbook.(2022). http://tjj.gz.gov.cn/datav/admin/home/www_nj/

Huang, F. (2023). Aging Population: China's Guangzhou steps up elderly care with focus on neighborhood programs. CGTN.

IEA. (2021). An energy sector roadmap to carbon neutrality in China. https://www.iea.org/reports/an-energy-sector-roadmap-to-carbon-neutrality-in-china/executive-summary

Lushan, H. (2021, June 23). Shanghai leads way in China’s carbon transition. China Dialogue. https://chinadialogue.net/en/cities/shanghai-leads-way-in-chinas-carbon-transition/

Shanghai Statistical Yearbook. (2022).

UNEP. (2021).Climate Action Note - data You Need to Know. https://www.unep.org/explore-topics/climate-action/what-we-do/climate-action-note/state-of-climate.html

United Nations. (2019). World population prospects 2019. https://population.un.org/wpp/

World Bank. (2022). Population ages 65 and above (% of total population) - China . https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS?locations=CN