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Research on the Relationship between Economic Structural Adjustment and Air Quality Changes in Shanghai

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Abstract: In recent years, Shanghai, as the economic center of China, has undergone significant economic structural adjustments. These adjustments are reflected not only in changes in the industrial structure but also in the optimization of the energy structure and the transformation of urban planning. As economic development continues, air quality issues have gradually become a focal point of public concern. Although the economic growth rate in Shanghai has slowed, the optimization and upgrading of its economic structure have provided opportunities to improve environmental quality. This study aims to explore the relationship between economic structural adjustments and air quality changes in Shanghai, providing policymakers with scientific evidence to balance economic development and environmental protection.

1. Introduction

Research on the relationship between economic structural adjustment and air quality, both domestically and internationally, indicates that adjustments in industrial structure have a significant impact on environmental quality improvement. Smith and Johnson pointed out in their study that developed countries achieved a notable reduction in pollutant emissions through industrial restructuring during their economic development. This finding provides an important basis for understanding the relationship between economic structural adjustment and environmental quality[1]. In China, Li Ming further validated the correlation between economic structural adjustment and air quality improvement through empirical studies on Beijing, Shanghai, and Guangzhou, particularly highlighting the positive impact of the decrease in the proportion of the secondary industry and the increase in the proportion of the tertiary industry on air quality[2].

Wang emphasized the dynamic relationship between economic structure and environmental pollution in Chinese cities, demonstrating that there is a significant synergy between pollution control and industrial upgrading during economic structural adjustment[3]. Zhang and Wang, in their study on the relationship between economic transition and air pollution in Chinese cities, revealed the environmental challenges during economic transitions and stressed the crucial role of policy interventions in mitigating air pollution[4]. Specifically in Shanghai, Liu found through an empirical analysis of economic structural transformation and air pollution prevention that as the proportion of

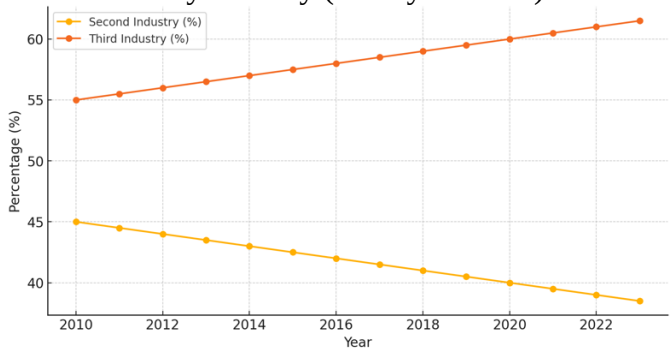
the secondary industry in Shanghai gradually decreased and the tertiary industry rapidly expanded, air quality significantly improved[5]. This research provides valuable case evidence for our study, further supporting the importance of economic structural adjustment in improving air quality.

In this research, we build upon these previous research findings by employing time series analysis and multiple linear regression models to deeply explore the impact of economic structural adjustment on air quality in Shanghai from 2010 to 2023. Through the analysis of this data, we have verified the significant relationship between industrial structure adjustment and air quality improvement, providing a scientific basis for further optimizing economic structures to enhance environmental quality.

2. Data Sources and Description

The data used in this study primarily comes from two authoritative institutions: the Shanghai Municipal Bureau of Statistics and the Shanghai Environmental Monitoring Center.

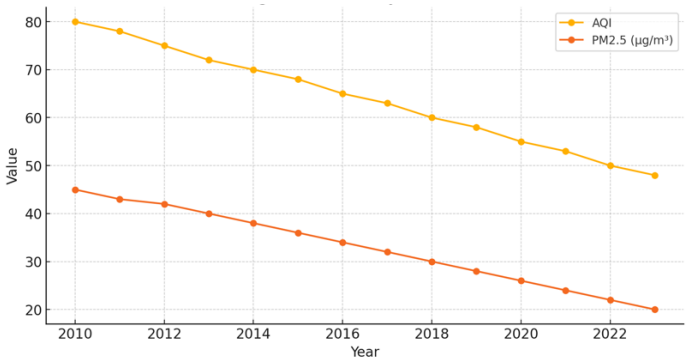
1) Shanghai Municipal Bureau of Statistics: This institution provided data on the development of various industries in Shanghai from 2010 to 2023, particularly focusing on the secondary and tertiary industries (Figure 1). The data includes key economic indicators such as the GDP share, output value, and employment figures of each industry. These indicators are used to measure the adjustments in the economic structure, with a specific emphasis on the relative proportions of the secondary industry (mainly manufacturing) and the tertiary industry (mainly services) within the overall economy.



Note- source: Shanghai Municipal Bureau of Statistics

Figure 1: Shanghai Industry Structure (2010year-2023year)

This figure shows the changes in the proportion of the secondary and tertiary industries in Shanghai's economic structure. The proportion of the secondary industry gradually decreases, while the proportion of the tertiary industry gradually increases, reflecting the trend of economic structural adjustment in Shanghai.



Note- source: Shanghai Environmental Monitoring Center

Figure 2: Shanghai Air Quality (2010year-2023year)

2) Shanghai Environmental Monitoring Center: Provided air quality data for Shanghai from 2010 to 2023, including the Air Quality Index (AQI) as well as the annual average concentrations of key pollutants such as PM2.5, PM10, SO2, and NO2. This data is used to analyze trends in air quality changes (Figure 2).

3. Construction of the Research Model

To quantify the impact of economic structural adjustments on air quality, we constructed a multiple linear regression model. The primary purpose of this model is to determine the extent to which adjustments in industrial structure (i.e., the changes in the proportions of the secondary and tertiary industries) affect the Air Quality Index (AQI) through regression analysis. The model takes key indicators of industrial structural adjustments as independent variables and the AQI as the dependent variable.

$$AQI_t = \alpha + \beta_1 * Proportion\ of\ Secondary\ Industry_t + \beta_2 * Proportion\ of\ Tertiary\ Industry_t + \epsilon_t$$

In this model:

AQI_t: Represents the Air Quality Index in year t for Shanghai. This indicator synthesizes the concentrations of multiple pollutants and reflects the overall level of air quality.

$Proportion\ of\ Secondary\ Industry_t$: Represents the proportion of the secondary industry in the overall economic structure in year t. The secondary industry typically includes manufacturing and construction, which are often major sources of pollution.

$Proportion\ of\ Tertiary\ Industry_t$: Represents the proportion of the tertiary industry in the overall economic structure in year t. The tertiary industry mainly includes services and high-tech industries, which are usually associated with lower levels of pollution.

α: Is the intercept term of the model, representing the AQI value when the independent variables are zero.

β_1 and β_2: Are the regression coefficients for the proportions of the secondary and tertiary industries, respectively. These coefficients reflect the marginal impact of changes in each industry's proportion on the AQI.

ϵ_t : Is the random error term, representing unexplained random factors or potential other influencing factors in the model.

(1) Model Interpretation

By estimating the regression coefficients in the model, we can draw the following inferences:

β_1: If positive, it indicates that an increase in the proportion of the secondary industry leads to a deterioration in air quality (an increase in AQI); if negative, it suggests that an increase in the proportion of the secondary industry might improve air quality (a decrease in AQI).

β_2: If negative, it indicates that an increase in the proportion of the tertiary industry contributes to an improvement in air quality (a decrease in AQI); if positive, it implies that the expansion of the tertiary industry might negatively impact air quality, although this situation is relatively rare.

Through this model, the study can specifically quantify the actual impact of changes in Shanghai's economic structure on air quality. For example, if the analysis results show that β_1 is significantly positive while β_2 is significantly negative, it can be concluded that the reduction of the secondary industry and the expansion of the tertiary industry are key drivers of air quality improvement in Shanghai.

(2) Potential Issues and Directions for Improvement

Although the multiple linear regression model performs well in explaining linear relationships between variables, there are still some potential issues to consider:

Multicollinearity: If there is strong correlation among the independent variables, it may lead to instability in the regression coefficients. Techniques such as VIF (Variance Inflation Factor) should be introduced for detection and correction.

Omission of Exogenous Variables: Air quality may also be influenced by other factors, such as population density, traffic conditions, and energy structure. Therefore, future research could consider incorporating more exogenous variables to enhance the explanatory power of the model.

4. Empirical Analysis

Based on the figures and data presented above, this study conducted an empirical analysis of Shanghai's data from 2010 to 2023. The analysis results show that as the proportion of the secondary industry gradually decreased and the proportion of the tertiary industry correspondingly increased, the air quality in Shanghai significantly improved. Specifically, the annual average concentration of PM2.5 decreased from 45 micrograms per cubic meter in 2010 to 22 micrograms per cubic meter in 2023. Similarly, the annual average value of the Air Quality Index (AQI) also exhibited a consistent downward trend over this period.

Figure 1 illustrates the relationship between the proportion of the secondary industry and PM2.5 concentration in Shanghai. The data clearly indicates that as the proportion of the secondary industry decreases, PM2.5 concentration shows a notable decline. This suggests that the contraction of the secondary industry, which traditionally includes high-polluting sectors such as manufacturing and construction, has positively contributed to the reduction of particulate matter pollution in the atmosphere. Figure 2, on the other hand, demonstrates the relationship between the proportion of the tertiary industry and the Air Quality Index (AQI). The figure highlights that as the proportion of the tertiary industry increases, air quality has significantly improved. The tertiary industry, which includes services and high-tech industries, typically generates less pollution compared to traditional industrial sectors, thereby contributing to lower AQI values and an overall improvement in air quality.

These findings indicate that economic structural adjustments, particularly the rapid expansion of the service sector and the relative contraction of the manufacturing sector, have played a crucial role in the significant improvement of air quality in Shanghai. The data shows that Shanghai’s strategic shift towards a more service-oriented economy has had a significant positive impact on reducing environmental pollution and enhancing public health outcomes. The development of the service sector not only drives economic growth but also plays an important role in environmental protection. The service sector, which includes finance, education, healthcare, high-tech, and information technology, is characterized by lower consumption of natural resources and reduced pollutant emissions. Therefore, as the proportion of the service sector in the economy continues to increase, Shanghai’s environmental burden has been alleviated, leading to significant improvements in air quality. This transition not only helps reduce the environmental pressure from traditional industries but also enhances the city's livability by providing residents with a cleaner living environment. Furthermore, the contraction of the manufacturing sector is particularly evident in the gradual phasing out of high-pollution, high-energy-consumption industries. These industries were once the backbone of Shanghai's economy, but with increasingly stringent environmental regulations and advances in technology, their relative importance has gradually diminished. As the government has promoted economic structural adjustments, it has effectively reduced industrial emissions into the atmosphere by implementing environmental protection policies and strengthening pollution control measures, which are crucial for improving air quality.

Through economic structural adjustments, especially the expansion of the service sector and the optimization of the manufacturing sector, Shanghai has not only achieved sustainable economic growth but also significantly improved environmental quality. This successful experience can serve

as a valuable reference for other cities, promoting the implementation of more comprehensive strategies for sustainable economic and environmental development. Policymakers should continue to support this transition process to ensure a balance between economic development and environmental protection in the future.

5. Conclusion and Recommendations

This research, through an in-depth analysis of Shanghai's data from 2010 to 2023, has established a significant and robust correlation between economic structural adjustments and changes in air quality. The findings indicate that the reduction in the proportion of the secondary industry, coupled with the rise in the proportion of the tertiary industry, has played a crucial role in the substantial improvement of air quality in Shanghai over the analyzed period.

The secondary industry, traditionally dominated by manufacturing and construction sectors, is often associated with higher levels of pollution due to the intensive use of energy and raw materials, leading to significant emissions of pollutants. The observed decline in its share within the overall economic structure has likely contributed to the reduction of pollutants such as PM2.5, which are known to have adverse effects on public health and the environment. On the other hand, the tertiary industry, which includes services, finance, and technology sectors, generally has a lower environmental impact due to its less resource-intensive nature. The increasing share of this sector has not only supported economic growth but also facilitated a cleaner environment.

Given these findings, it is imperative that policymakers take proactive steps to continue promoting the optimization of industrial structures as part of future economic planning. This can be achieved by encouraging the development of high value-added, low-pollution industries within the tertiary sector. Such industries not only contribute to sustainable economic growth but also align with the broader goals of environmental sustainability. Furthermore, while the shift towards a service-oriented economy is beneficial, it is equally important to maintain stringent control over the expansion of high-pollution sectors within the secondary industry. This could involve the implementation of stricter regulations and standards for industries that are known to have significant environmental impacts.

The role of the government in enhancing environmental governance cannot be overstated. There is a need for the government to implement more rigorous emission standards that can effectively curb the release of harmful pollutants into the atmosphere. Such standards should be regularly updated to reflect the latest scientific understanding of air pollution and its health impacts. Additionally, the promotion and adoption of green energy technologies should be prioritized as part of the broader strategy to reduce reliance on fossil fuels and mitigate their associated environmental effects. This could include investing in renewable energy sources such as solar, wind, and hydroelectric power, which have the potential to significantly lower greenhouse gas emissions.

The coordinated efforts to optimize the industrial structure and strengthen environmental governance will be essential in ensuring that Shanghai can continue to develop economically while also improving and sustaining air quality. These measures are not only critical for the health and well-being of the city's residents but also serve as a model for other cities facing similar challenges. The integration of economic and environmental policies will be key to achieving a sustainable future where economic growth and environmental protection go hand in hand.

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