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THE IMPACT OF URBAN EXPANSION ON THE GREEN ECONOMY DEVELOPMENT IN GUANGDONG PROVINCE

JIANG KE [1] and Dr. PEERAWEE THEPPRATUENGTHIP [2]

[1,2] Suan Sunandha Rajabhat University, Bangkok, Thailand. Email: [1]S64584945051@ssru.ac.th

Abstract

This article takes Guangdong Province, China as the research object, and investigates 568 samples of the civil service system in Guangdong Province through a questionnaire survey to explore the mutual influence relationship and internal influence mechanism between urban expansion and green economy development. Through empirical research using structural equation modeling (SEM), the article concludes that urban expansion has a significant negative impact on the development of green economy, a positive impact on energy consumption, a negative impact on environmental quality, a negative impact on energy consumption, and a positive impact on environmental quality. Further analysis of indirect effects reveals that energy consumption and environmental quality have a mediating effect between urban expansion and green economic development. Therefore, in order to achieve sustainable development of the green economy, comprehensive measures need to be taken to coordinate the relationship between these three factors, namely promoting the rationalization of urban expansion, improving energy efficiency, and strengthening environmental protection and governance.

Keywords: Urban Expansion; Green Economy Development; Energy Consumption; Environmental Quality; Guangdong Province.

1. INTRODUCTION

The core goal of green economy development is to achieve effective utilization of resources, protection of ecological environment, sustainable economic and social development, and achieve win-win outcomes for all parties (Yang et al., 2011). Therefore, green economic growth needs to comprehensively consider the relationship between resource conservation, ecological environment improvement, and economic development, while also taking into account the sustainable development of economic benefits and production methods (Long, 2024). The contradiction between green economic growth and resource environment is becoming increasingly prominent. In the context of the new normal, China's economic development mode has gradually shifted from a "speed first" to a "quality first" stage, and high-quality economic development has become a basic requirement for economic development in the new era.

The long-term extensive development mode has brought dual pressures of severe resource shortage and environmental pollution to China's economic and social development. On the one hand, resources and energy are increasingly constraining economic growth; On the other hand, economic development is facing severe ecological and environmental problems. In 2012, the World Bank and the Organization for Economic Cooperation and Development (OECD) defined green development as ensuring the efficient use of natural resources in the process of economic development. The United Nations Environment Programme (UNEP) has further expanded existing concepts by introducing the concept of green development to improve the living environment and stabilize social development. By 2016, the United Nations had elevated

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inclusive green development to a new type of sustainable development, and green development in countries around the world had entered a new stage. In 2021, the State Council further issued the "Opinions on Promoting Green Development in Urban and Rural Construction", introducing the concept of green development into the construction of new urbanization and emphasizing the importance of green urbanization.

The rapid advancement of urbanization has created a "Chinese miracle", but the extensive model of "seeking development through land" has resulted in negative impacts such as low land use efficiency and improper use. This article takes Guangdong Province and its subordinate cities in China as the research object, focusing on the changes in green economy development during urban expansion, and analyzing the mediating role of energy consumption and environmental quality between urban expansion and green economy development. The article believes that it is necessary and urgent to study the development of green economy in China's urbanization process, whether it is the key task of optimizing the layout of urbanization or achieving the long-term goal of sustainable economic development. This can provide theoretical reference and guidance for the deep integration of new urbanization and green development concepts, and the construction of a new development pattern.

2. LITERATURE REVIEW

2.1 Urban Expansion and Green Economy Development

Some scholars believe that urban expansion has a negative impact on productivity, and they often examine it from the perspective of urban sprawl. For example, drawing inspiration from the theory of urban agglomerations, data from 357 metropolitan areas in the United States from 1990 to 2001 were used (Farah, 2021). They conducted empirical tests on the relationship between economic performance and urban expansion in metropolitan areas of the United States using OLS and instrumental variable methods.

This study found a negative correlation between urban sprawl and urban productivity. A specialized urban sprawl index was constructed using panel data of Chinese cities from 2000 to 2002 and global nighttime light data. Research has found that urban sprawl can inhibit the improvement of total factor productivity (Qin and Liu, 2020). In addition, using urban panel data and DEA method to calculate the total factor productivity of prefecture level cities, the spatial differentiation of the impact of urban expansion on urban total factor productivity is empirically tested.

Research has found that urban sprawl suppresses the growth of total factor productivity in cities, and this impact varies spatially (Wang, 2022). Based on the industrial dynamic agglomeration index and spatial Durbin model, the relationship between urban expansion and productivity was explored. Research has shown that urban sprawl suppresses productivity growth by reducing industrial agglomeration levels, with a more pronounced effect from 2000 to 2006 (Hao, 2020). Urban expansion can lead to increased energy consumption, worsening air pollution, reducing urban green spaces, and increasing the burden on ecosystems (Johnson, 2021).

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The cost of low-density urban expansion is that urban construction encroaches on agricultural and forestry land, leading to a weakened self-purification capacity of the ecological environment and a decrease in urban green production efficiency (Borrego et al., 2024). Currently, some scholars believe that there is a non-linear or more complex relationship between urban expansion and productivity. Using the statistical data of Chinese cities from 2006 to 2012, analyze the impact path of urban expansion on economic efficiency and explore the role of urban expansion on urban economic efficiency. Research has found that there is an inverted U-shaped relationship between urban land expansion and scale efficiency, while this is not the case in the eastern region (Zhao, 2021).

Using data from 286 cities in China from 1997 to 2013 as the research object, it was found that there is uncertainty in the direction of the impact of urban sprawl on urban productivity, which depends on industrial structure and city size. The interactive relationship between the expansion of provincial construction land and economic growth efficiency in China was dynamically analyzed using a panel VAR model. Research has shown that the expansion of urban construction land can suppress economic growth efficiency in the short term, but the long-term impact is not significant (Wei Shouhua, 2023). Therefore, this article proposes H1: Urban expansion has a significant negative impact on the development of green economy.

2.2 Urban Expansion and Energy Consumption

In the past few decades, China's urbanization process has significantly accelerated. With the rapid expansion of cities, problems such as resource scarcity and environmental pollution have emerged, hindering the sustainable development of cities. Improving energy utilization efficiency and reducing energy intensity are important means to alleviate the contradiction between ecological environment and economic growth.

The general factors that affect energy consumption include agglomeration, economic development, industrial structure, energy prices, etc. High density production and daily life can effectively reduce transportation costs, accelerate knowledge dissemination, and lower unit energy consumption. Industrial agglomeration is beneficial for improving energy utilization efficiency and reducing energy consumption. Economic level is a key factor affecting energy consumption (Cheng, 2020). Economic growth is the main driving force behind energy consumption. There are differences in the impact of increasing income levels of urban and rural residents on energy consumption (Shao, 2021). The increase in rural residents' income has increased energy consumption, while the improvement in urban residents' income level is beneficial for energy conservation. The rise in energy prices has prompted enterprises to adopt new energy-saving technologies, improve enterprise management, and enhance energy utilization efficiency (Li, 2021).

This study used statistical data from 1993 to 2007 to explore the relationship between energy prices and energy consumption in China. Research has found that rising energy prices will reduce energy consumption in China's industrial sector. Compared with energy prices, technological innovation is also a major factor affecting energy consumption (Cui, 2020). With the improvement of technological innovation level, the energy consumption level has

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correspondingly decreased (Zhang, 2022). Using panel data from 285 cities from 2006 to 2015, it was found that urban expansion significantly affects energy consumption, and this impact has spatial spillover effects (Liu, 2022). At the national level, the relationship between urban size and energy consumption in seven regions including East Asia, Western Europe, and Latin America was explored. Research has found that for the vast majority of countries, urban size promotes energy consumption (Usama, 2021). Therefore, this article proposes H2: Urban expansion has a positive impact on energy consumption.

2.3 Urban Expansion and Environmental Quality

From the actual situation in our country, the impact of urban expansion on environmental quality also has negative characteristics. Since the 19th century, the negative impact of urban expansion has received widespread attention in Britain; In the 1930s, it expanded to the political field. With the continuous disorderly expansion of cities, urban development has brought negative impacts on resource management, energy protection, environmental sanitation, and sustainable urban development. The research on urban expansion control originated in the United States. Early criticism of urban expansion mainly focused on the destruction of urban landscapes, while discussions on urban expansion control policies mainly focused on concerns about the efficiency of urban sprawl (Jiang, 2022). At present, research on the impact of urban expansion on environmental quality is one of the mainstream studies abroad.

Urban expansion has had a significant impact on the environment, with urban growth in Switzerland and Europe primarily driven by the consumption of agricultural land (Muller, 2021). With the acceleration of urbanization and rapid economic development, the population has significantly increased, leading to problems such as disorderly expansion of built-up areas, crowded population and transportation environments, shrinking green spaces, and worsening air pollution. Pollution emissions can affect environmental quality, and further pollution can have exposure effects (on humans and society). The decline in air quality can lead to environmental pollution, and pollution exposure can lead to a decline in health and well-being. All of these have forced the economic system to start controlling pollution and improving environmental quality (Ian, 2021). Therefore, this article proposes H3: Urban expansion has a negative impact on environmental quality.

2.4 Energy Consumption and Green Economy Development

Overall, the negative impact of energy consumption on the development of green economy has been demonstrated and recognized by most scholars. Chapter 39 of the "14th Five Year Plan" proposes to comprehensively improve resource utilization efficiency, adhere to the principle of prioritizing energy conservation, deepen energy conservation in industries, buildings, transportation, public institutions, and other fields, promote energy efficiency improvement in emerging fields such as 5G and big data centers, strengthen energy-saving management of key energy consuming units, carry out key projects such as energy system optimization and energy-saving technology upgrading, accelerate the formulation and revision of mandatory national standards such as energy consumption limits and product equipment energy efficiency.

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Vigorously developing the green economy, resolutely stopping the blind development of high energy consumption and high emission projects, and making positive progress in green transformation.

From a foreign perspective, Liu (2015) mentioned in his research on South Korea's green and low-carbon economy that promoting the scientific development of low-carbon economy, reducing energy consumption, and promoting the development of green economy are beneficial. Gradually improving the efficiency evaluation system for local environmental protection expenditures, enhancing the efficiency of energy conservation and environmental protection expenditures, and promoting "green development" (He Lidao et al., 2018) also mentioned this point. Chen Jie et al. (2020) found through the Henson threshold regression method that green credit can effectively play an important role in energy conservation, emission reduction, and economic growth, which is conducive to formulating policy incentives and improving the level of green development.

Chen et al. (2022) studied the efficiency and impact of green economy development in the Yellow River Basin under the background of carbon neutrality, and proposed that attention should be paid to the impact of industrial structure upgrading on green economy efficiency in the Yellow River Basin, and energy consumption should be reduced according to local conditions; We should also strengthen technological innovation that affects green industries and help improve the efficiency of green economic development. Similar regional research conclusions have also been replicated in Yancheng (Gu, 2023). Therefore, this article proposes H4: Energy consumption has a negative impact on the development of green economy.

2.5 Environmental Quality and Green Economy Development

Early research on environmental quality was mostly based on the perspective of economic growth. With the continuous deepening of financial promotion of economic growth, scholars have gradually paid attention to the correlation between financial development and environmental impact. More and more research is beginning to consider the role of financial development in environmental protection. Pioneering research has been conducted on the relationship between economic development and environmental quality, and the results indicate that economic development can reduce pollutant emissions and improve environmental quality (Tamazian et al., 2022).

Subsequently, many empirical articles exploring the relationship between economic development and the environment have also emerged abroad, but the conclusions differ greatly. Contrary to the above research findings, an empirical study on India confirms that economic development leads to an increase in pollutant emissions, exacerbating environmental degradation (Boutabba, 2024). Unlike the aforementioned research which suggests a linear relationship between economic development and the environment, the UAE study found an inverted U-shaped relationship between economic development and carbon dioxide emissions, with carbon emissions showing an evolutionary trend of first increasing and then decreasing as the level of economic development deepens.

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At present, there is relatively little research on the relationship between China's economic development and environmental pollution, and there is a significant gap in conclusions. Research has confirmed that China's economic development can reduce pollution emissions and improve the environment (Jalil, 2021). The empirical results indicate that economic development leads to an increase in pollutants (Zhang et al., 2021), and there is an inverted U-shaped relationship between carbon emissions. Therefore, this article proposes H5: Environmental quality has a positive impact on the development of green economy. In summary, hypothesis H6 can be further proposed: energy consumption has a mediating effect between urban expansion and green economic development; Assuming H7: Environmental quality has a mediating effect between urban expansion and green economic development. The conceptual model is as follows:

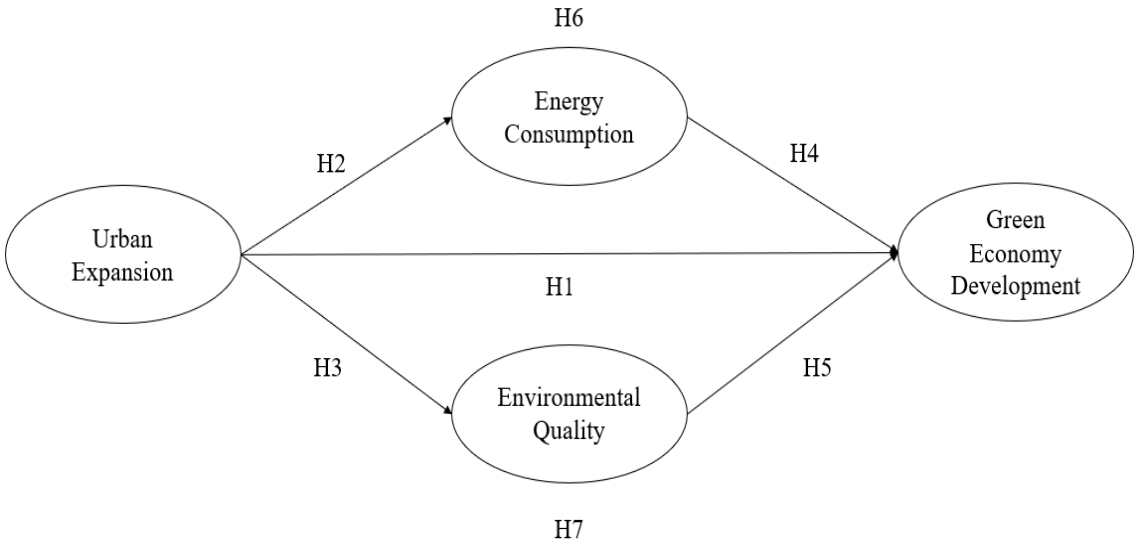

Figure 1: Conceptual Model

3. RESEARCH DESIGN

3.1 Sample sources and data collection

After pre testing, we have confirmed the official questionnaire. In order to ensure the efficiency and effectiveness of questionnaire collection, our questionnaire distribution method is synchronized through online Wenjuanxing and offline documents. The main distribution targets are various public officials in the civil service system of Guangdong Province. Among tens of thousands of sample sizes, we collected 596 questionnaires through random sampling, stratified sampling and other methods. After removing obviously invalid questionnaires, we retained 568 valid questionnaires, with a questionnaire effectiveness rate of 95%.

From the perspective of urban distribution, the overall coverage covers 21 cities in Guangdong Province, and the coverage ratio is balanced. Relatively speaking, the city level with the highest proportion is "Level 9", reaching 29.05%. The sample comes from the two most developed

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cities in Guangdong Province, Guangzhou and Shenzhen; From the perspective of the research subjects, 50.70% are undergraduate students, which conforms to the talent structure rules of the civil service system; From the perspective of job categories, the sample has a complete coverage rate for the three categories of the civil service system, namely Integrated Management Professional skills、Administrative law enforcement，

Among them, there are relatively more professional and technical personnel, so they have a better understanding of the variables and themes studied in this article; Finally, in terms of years of employment, 6-10 years has the highest proportion, accounting for 45.25%. Considering that witnessing urban expansion takes time, we believe that the sampling here is scientific and logical. Overall, the demographic variables of the sample have a wide coverage and balanced distribution, which meets the basic requirements for further analysis.

3.2 Variable measurement

To ensure the reliability and validity of the questionnaire, this study used mature scales from existing literature and made appropriate adjustments to the scales based on the purpose of this study and pre-test results. All items on the scale are designed using a Likert 5-point scale, where 1 represents' strongly disagree 'and 5 represents' strongly agree'.

The independent variable of this article is urban expansion (UC), with reference and inspiration from Moraes (2024); Li's (2022) viewpoint measures urban expansion through three dimensions: population agglomeration (PA), industrial agglomeration (IA), and economic agglomeration (EA), with 18 items; The dependent variable of this article is Green Economy Development (GED), with reference and inspiration from Belinska (2023); Li's (2022) viewpoint measures the development of green economy in three dimensions: Green Economy Level (GEL), Green Transformation (GT), and Green Economic Efficiency (GEE), with 18 items; The mediating variables in this article are energy consumption (EC) and environmental quality (EQ). Energy consumption refers to the views of Yang (2009) and He et al. (2016), and measures 18 items in three dimensions: Renewable Energy (RE), Non Renewable Energy (NRE), and Artificial Energy (AE); The environmental quality reference draws on the views of Sanjit (2024) and Zhou et al. (2018), measuring 18 items in three dimensions: Air Quality (AQ), Water Environment Quality (WQ), and Green Coverage Rate (GCR).

4. EMPIRICAL ANALYSIS

4.1 Descriptive statistics

Descriptive statistical analysis of research variables helps to quickly understand the characteristics and distribution of data. Especially the maximum and minimum values help us determine the range of the data, the mean and standard deviation help us determine the centrality and dispersion of the data, and skewness and kurtosis help us understand whether the distribution pattern of the data is normal. Descriptive statistical analysis was conducted using SPSS, and it was found that there were no outliers in the various data of the sample. The next step of analysis can be carried out.

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4.2 Reliability and Validity Analysis

1. Reliability analysis

We will use SPSS26 and SMART PLS4 software to conduct reliability tests on 568 samples. The reliability of the present scale was analyzed in five ways: corrected item-total score correlations for each dimension, Cronbach's alpha coefficients after deleting an item, Cronbach's alpha coefficients, combined reliability (CR), and average variance extracted (AVE).

After software analysis,the reliability coefficient values of all 12 dimensions and 72 measurement items meet the requirements, and the reliability coefficient values of all dimensions of the scale are greater than 0.5, indicating high reliability quality of the research data. Among them, the Cronbach's alpha coefficients of all first-order and second-order variables are greater than 0.8, The CR values are all above 0.7, and the AVE values are all above 0.5, indicating good combination reliability.

2. Validity analysis

After completing the content validity test, it is necessary to determine the suitability of information extraction through KMO value and Bartlett sphericity test, analyze the KMO value. From the SPSS, it can be seen that both first-order and second-order variables have KMO values and Bartlett's sphericity test between 0.7-0.9, which indirectly reflects good validity.

The discriminant validity test is usually performed using the heterotrait monotrait (HTMT) test and the Fornell Larker criterion, and it can also be verified through Cross loading. These methods each have their own advantages, but the cross loading and Fornell Rocker criterion methods are still mainstream. The scale has also been proven effective after being tested in the above three ways. And all of them VIF values did not exceed 5, which fully indicates that the data in this study did not exhibit serious multicollinearity issues.

4.3 Structural Equation Modeling Verification

In structural equation modeling (SEM) analysis, the main role of analyzing structural models is to assess the causal relationships and path coefficients between variables. Figure 2 shows the exported path diagram analyzed using SMART PLS4 software, the R-variance and adjusted R^2 of the latent variables are both above 0.6, indicating that the explanatory power of this model is good and can describe the relationship between potential variables with more accuracy.

In this study, the Q^2 values of the latent variables are above 0.4. It is worth mentioning that the Q^2 values of all the latent variables are greater than 0, which is a good indication that the model has good correlation in predicting these variables. The model fit of this study is shown the SRMR value is 0.089, which indicates that the simulation in this study is a good fit.

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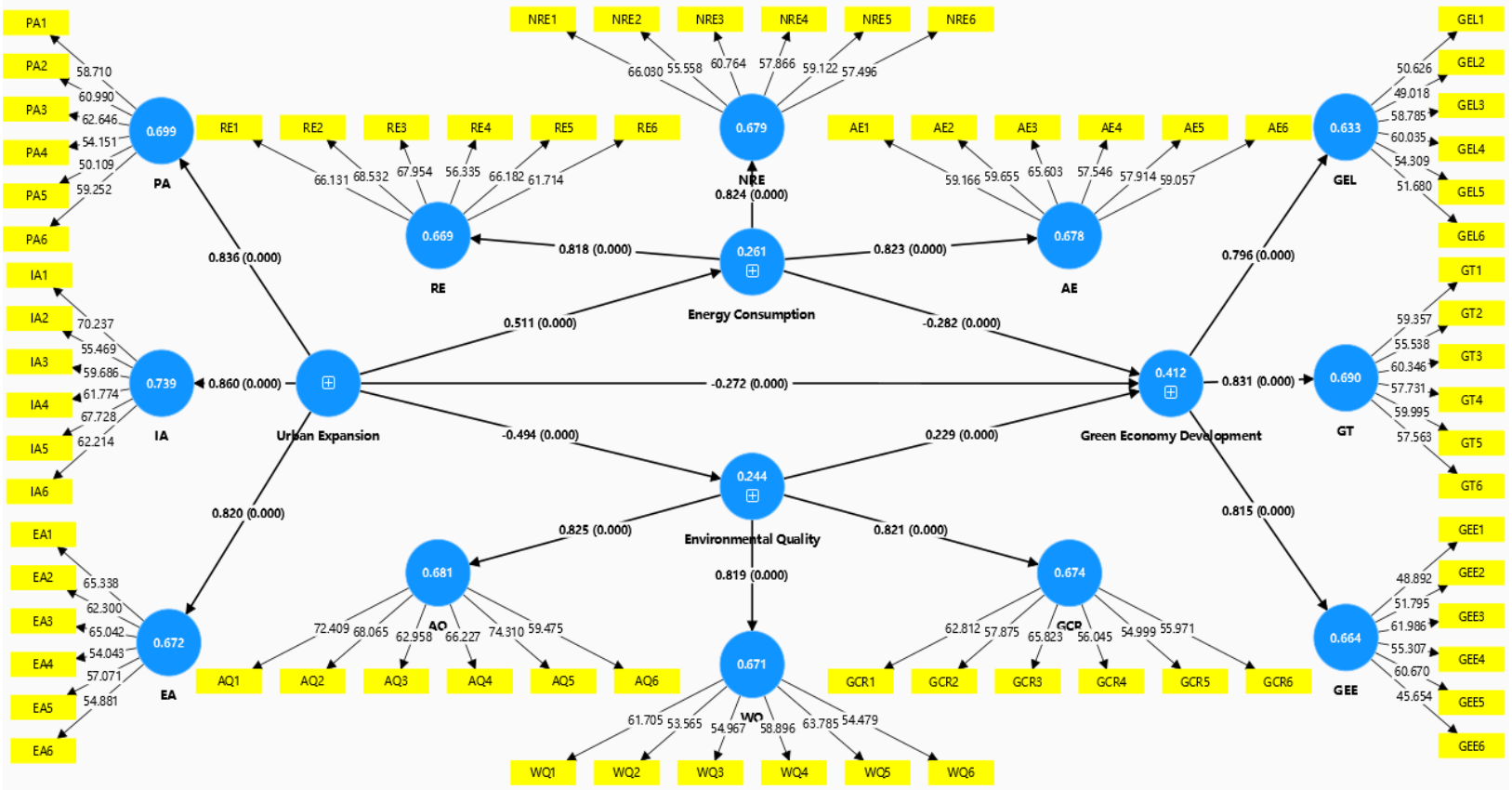

Figure 2: Path Analysis in SmartPLS4

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1. Direct Path Analysis

Table 1 is a table of direct path impact correlation coefficients, indicating the direct impact relationship between variables.

(1) The path coefficient of Urban Expansion on Green Economy Development is -0.272,(t =6.211, p<0.05), indicating that Urban Expansion has a significantly negative impact on Green Economy Development, which supporting Hypothesis 1.

(2) The path coefficient of Urban Expansion on Energy Consumption is 0.511,(t =15.901, p<0.01), indicating that Urban Expansion has a significantly positive impact on Energy Consumption, which supporting Hypothesis 2.

(3) The path coefficient of Urban Expansion on Environmental Quality is -0.494,(t =15.258, p<0.01), indicating that Urban Expansion has a significantly negative impact on Environmental Quality, which supporting Hypothesis 3.

(4) The path coefficient of Energy Consumption on Green Economy Development is -0.282,(t = 6.654, p<0.01), indicating that Energy Consumption has a significantly negative impact on Green Economy Development, which supporting Hypothesis 4.

(5) The path coefficient of Environmental Quality on Green Economy Development is 0.229,(t=5.491, p<0.01), indicating that Environmental Quality has a significantly positive impact on Green Economy Development, which supporting Hypothesis 5.

Table 1: Direct Path Coefficients

Direct Path	Hypothesis	O	M	STDEV	T	P	2.5%	97.5%
Urban Expansion -> Green Economy Development	H1	-0.272	-0.272	0.044	6.211	0.000	-0.358	-0.186
Urban Expansion -> Energy Consumption	H2	0.511	0.512	0.032	15.901	0.000	0.448	0.573
Urban Expansion -> Environmental Quality	H3	-0.494	-0.495	0.032	15.258	0.000	-0.557	-0.428
Energy Consumption -> Green Economy Development	H4	-0.282	-0.282	0.042	6.654	0.000	-0.365	-0.200
Environmental Quality -> Green Economy Development	H5	0.229	0.229	0.042	5.491	0.000	0.146	0.308

2. Indirect path analysis

From the path coefficient results derived from SMARTPLS4.0, we can further discover some indirect effects, as shown in Table2:

(1) Urban Expansion -> Environmental Quality -> Green Economy Development, with a path coefficient of -0.113 (t=5.176, p<0.01), indicating that Environmental Quality has a mediating effect on the impact of Urban Expansion on Green Economy Development, which supporting Hypothesis 6.

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(2) Urban Expansion -> Energy Consumption -> Green Economy Development, with a path coefficient of -0.144 (t=6.010, p<0.05), indicating that Energy Consumption has a mediating effect on the impact of Urban Expansion on Green Economy Development, which supporting Hypothesis 7.

Table 2: Indirect Path Coefficients

Indirect Path	Hypothesis	O	M	STDEV	T	P	2.5%	97.5%
Urban Expansion -> Environmental Quality -> Green Economy Development	H6	-0.113	-0.113	0.022	5.176	0.000	-0.156	-0.072
Urban Expansion -> Energy Consumption -> Green Economy Development	H7	-0.144	-0.145	0.024	6.010	0.000	-0.193	-0.099

5. CONCLUSION AND DISCUSSION

5.1 Conclusion

This article takes Guangdong Province, China as the research object, and investigates 568 samples of the civil service system in Guangdong Province through a questionnaire survey to explore the mutual influence relationship and internal influence mechanism between urban expansion and green economy development. Through empirical research using structural equation modeling (SEM), the article concludes that urban expansion has a significant negative impact on the development of green economy, a positive impact on energy consumption, a negative impact on environmental quality, a negative impact on energy consumption, and a positive impact on environmental quality. Further analysis of indirect effects reveals that energy consumption and environmental quality have a mediating effect between urban expansion and green economic development. The research conclusion of the article further enriches the theoretical model of the relationship between urban expansion and green economic development, providing theoretical support for subsequent research; In practice, it provides policy guidance or inspiration for the government in promoting regional green economic development.

5.2 Discussion

Based on the above conclusions, we will further believe that the interaction and mutual influence between urban expansion, energy consumption, and environmental quality collectively have an impact on the development of green economy. In order to achieve sustainable development of the green economy, comprehensive measures need to be taken to coordinate the relationship between these three factors. Firstly, it is necessary to promote the rationalization of urban expansion, through scientific planning and management, to achieve the rationalization and orderliness of urban expansion, and to avoid disorderly expansion and resource waste; Secondly, it is to improve energy utilization efficiency, through technological innovation and policy guidance, to enhance energy utilization efficiency, reduce energy consumption and emissions, and promote the development and use of clean energy; Finally, it

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is necessary to strengthen environmental protection and governance, increase environmental protection efforts, strengthen pollution control and ecological restoration work, improve environmental quality, and provide a good ecological environment for the development of green economy. However, it should be noted that the impact mechanism of urban expansion, energy consumption, and environmental quality on the development of green economy is complex and variable. The article has certain limitations in measuring variables and selecting samples. Subsequent scholars can further explore from multiple dimensions and perspectives.

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