

A Study on the Coordinated Development of Population Growth and Social Security in Guangdong Province

Lu Zeng¹, Xusheng Zhang^{2,a,*}, Fei Mi²

¹Labor and Social Security, Guangdong Medical University, Dongguan, Guangdong, China

²Humanity and Management College, Guangdong Medical University, Dongguan, Guangdong, China

^azhangxusheng@gdmu.edu.cn

*Corresponding author: Xusheng Zhang

Abstract: This study aims to analyze the coordinated development of population growth and social security in Guangdong Province, and summarize the objective laws of development in various economic regions. The research aims to provide new insights for the government to promote the coordinated development of population growth and social security based on local conditions, formulate sustainable social security policies, improve the level of social security in Guangdong Province, and enrich the content of social security policy reform. The research methods include literature review, exploration of advanced theories and models from abroad, and processing of publicly available data from the Guangdong Provincial Government in 2020. Additionally, the study utilizes the principles of statistical measurement of variable coupling to calculate the coordination between population development and social security development in Guangdong Province, and explains the differences in coordination levels among different regions through empirical research methods. The results indicate a significant positive correlation between population development and social security development in most regions of Guangdong Province. Regions with higher levels of population development tend to have higher levels of social security, and there is a similar spatial distribution pattern between the two. However, there is also a significant imbalance in development among different regions. Based on the coordination level between population development and social security development, the Pearl River Delta region is categorized as having high-quality coordination, the mountainous areas are classified as moderately imbalanced, and the western and eastern regions are deemed severely imbalanced. In conclusion, data analysis suggests that the Guangdong Provincial Government needs to further deepen the reform of the social security system, promote economic integration, strengthen the construction of social security institutions, narrow the wealth gap between regions in Guangdong Province, maintain coordinated development among different regions, promote further economic development in Guangdong, attract more talent to stay in the province, and achieve the goal of shared economic development for all citizens.

Keywords: population development, social security development, coordination degree, coupling coordination degree

1. Introduction

1.1. Research Background

Since the emergence of human society, social security issues have always been present as they are essential for human survival and development. In fact, population issues are an aspect of development problems. Population is at the core of social life and is the target of social security, while population needs form the fundamental basis for the transformation of social security systems[1]. Thus, there is an inseparable relationship between social security and population development.

Since the reform and opening-up policy, China has transformed its enormous population burden into a demographic dividend, which has promoted rapid economic development and improvement in medical technology, leading to a significant enhancement in the quality of life for residents. The subsequent implementation of the one-child policy effectively controlled population growth and maintained a certain balance between population and the availability of production and living resources. However, the current declining marriage and birth rates have resulted in China no longer being a

country with a demographic dividend. On the other hand, due to the improved material living standards and rapid advances in life sciences research, life expectancy has been increasing. This has led to a lower birth rate for newborns compared to the growth rate of the elderly population, resulting in an increasing proportion of the elderly population. This, to some extent, has increased the dependency ratio and burden of supporting the elderly population, adding financial pressures to the social security system and greatly impacting it.

Furthermore, the scarcity of labor resources has resulted in a decrease in labor productivity, while industrialization and urbanization have led to population aging, inevitably causing changes in family structure and a decrease in family size. This further weakens the function of family support and poses significant challenges to the existing social security system model[1].

Therefore, to ensure people's well-being, the establishment and sustainable development of the social security system should continuously improve in response to changes in population development. Generally, discussions on population development indicators primarily focus on population structure and total population. The situation in Guangdong Province is particularly unique as it ranks first in terms of GDP and population among all provinces in China. In the seventh national census, the resident population in Guangdong reached a staggering 126,012,510 people, with a GDP of 11,076.094 billion yuan in the same year. However, when examining the region, the core area of the Pearl River Delta accounted for 61.91% of the total resident population in the province in 2020, while the coastal economic belt, including the eastern and western regions and the ecological development zone in the mountainous areas, accounted for 12.95%, 12.51%, and 12.63% of the total resident population, respectively [2]. In terms of GDP distribution, the core area of the Pearl River Delta accounted for 80.8% of the total in the province, while the eastern and western regions and the ecological development zone in the mountainous areas accounted for 6.4%, 7.0%, and 5.8%, respectively [3]. The significant disparity in population distribution and economic development among regions has had a profound impact on the social security development in Guangdong Province, and achieving coordinated development among these four regions has become a crucial factor in realizing the goals of the "13th Five-Year Plan" in Guangdong Province. Therefore, promoting economic development, improving the level of social security, and achieving coordination between population development and social security development while addressing the root causes of population issues have become focal points of attention in present-day Guangdong Province.

1.2. Significance of the Study

The natural structure of the population plays a crucial role in population reproduction. It is both the inevitable outcome and the foundation of population reproduction, exerting significant constraints on the scale and speed of population development. At the same time, the development of social security also imposes constraints on the natural structure of the population [4]. However, existing literature primarily focuses on the interactive research and impacts between population development trends and the level of social security, while research and analysis on the degree of coordination between population development and social security development are relatively limited.

This study aims to utilize the principles of variable coupling measurement in statistics to assess the degree of coordination between population development and social security development in Guangdong Province. Additionally, empirical research methods will be employed to explain the differences in coordination between different regions. Theoretically, this research can summarize the patterns of population development, provide new insights to enhance the level of coordination between population development and social security development among regions, broaden the perspective of government in formulating sustainable social security policies, and enrich the content of social security policy reforms. This study can contribute to the construction and reform of the social security system.

In practice, this research can promote the rational allocation of resources among regions, coordinate regional economic development, maximize the coordination of economic benefits and resource-environmental ecological benefits, and guide the rational distribution of population, contributing to social harmony and stable development. Furthermore, comprehensive improvement in population quality contributes to the establishment of a strong human resource country, promotes rapid development of productivity, and enhances national comprehensive strength, ensuring the stability of the country's political power. Moreover, this research can provide scientific directions and guidance for the development of the insurance industry, facilitate the establishment of insurance systems that are more suitable for the population, and improve the level of material security for the people.

1.3. Literature Review

1.3.1. Relationship between Population Mobility and Social Security Development

Population mobility refers to various short-term, repetitive, or cyclical movements of the population between regions. Since the reform and opening-up in China, population mobility has exhibited a trend from central and western regions to eastern and southeastern coastal areas, with the majority of mobile populations concentrated in economically developed regions such as Beijing, Shanghai, Guangzhou, and Shenzhen. This is mainly due to the higher degree of industrialization and urbanization in the eastern and southeastern coastal areas, which provide more employment opportunities and development space. The direction of labor mobility in China is highly sensitive to economic changes, and as the economic development process and economic situation vary across regions, the geographic characteristics of population mobility also undergo local changes [7]. This phenomenon reflects the imbalanced regional economic and social development in China. However, since social security in China is mostly coordinated at the provincial level, imbalances in the distribution of population mobility can have certain impacts on the development of social security.

In recent years, scholars from various countries have conducted extensive research on the coordination between population mobility and social security development, achieving remarkable research outcomes. Among them, representative studies in foreign literature include Doris Geide-Stevenson and Mun S. Ho's (2004) numerical simulation of an intergenerational overlapping model between two countries to study international labor migration under different social security system characteristics. The results indicate that, under all considered circumstances, immigration leads to temporary welfare losses for both countries in a self-sufficient steady state. In all cases, the characteristic of the transitional path is the temporary occurrence of dynamic inefficiency in one country [8]. China can refer to the population mobility characteristics under different social security systems in other countries to improve the level of social security for mobile populations and promote social progress. VeselaKovacheva, Dita Vogel, Xiaonan Zhang, and Bill Jordan (2012) conducted a comparative analysis of internal population migration in the European Union (EU) and China and found that the EU has a much more comprehensive social security level regarding internal migration, which is an aspect that China needs to learn from [9]. China can further improve and enhance the social security system for mobile populations by drawing lessons from how EU nationals can still protect citizens' rights during population mobility.

Representative studies in domestic literature include Shen Suyan, Xue Mengying, and Li Fang's (2022) analysis based on 2015 social survey data, using the propensity score matching method to explore the impact of social security participation on the perception of socioeconomic fairness among rural-urban and urban-urban mobile populations. The results indicate that social security participation can effectively improve the perceived socioeconomic fairness of mobile populations, especially between rural-urban areas. The government should pay attention to this phenomenon and guide population mobility reasonably [10]. However, this study also has certain limitations. For example, the 2015 social survey data have temporal limitations, as time has passed, and there have been significant changes in policies and the economy. Additionally, the definition of perceived socioeconomic fairness in the article only represents the individual perception of fairness at the economic and social levels, which has certain limitations. Scholar Huang Aijiao (2015) discusses the development rights of mobile populations and studies the guarantee methods for the development rights of mobile populations to improve their social security level, promote their development, and advance social progress [11]. The research conducted by this scholar is in line with the current societal demands. The development of mobile populations is often constrained by the influence of the household registration system and inadequate social security coverage, which can impede economic development and social integration. Therefore, it becomes particularly important to enhance the avenues of protection, deepen the reform of the household registration system, and improve the social security system when facing obstacles in realizing the development rights of mobile populations.

1.3.2. The relationship between population age structure and social security development

Population age structure reflects the proportion of different age groups within a certain region's total population. According to the data from the 7th National Population Census in China, in 2020, the birth rate was 7.52 per thousand, the marriage rate was only 5.4%, and the population aged 60 and above accounted for 18.7% (with 13.5% aged 65 and above). Compared with the 6th National Population Census, the proportion of the population aged 60 and above has increased by 5.44 percentage points (4.63 percentage points for the population aged 65 and above) [2]. According to the United Nations' standards, China is currently experiencing an aging population. The phenomena of low birth rates and

population aging are accelerating the disruption of the balance between population development and its production and livelihood resources.

Due to the issue of population aging faced by various countries, and the fact that population aging has spurred reforms in social security systems, scholars in recent years have conducted extensive academic discussions on the reform and sustainable development of population aging and social security levels. In foreign research, Mustafa Yavas and N. Gizem Bacaksizlar (2012) used system dynamics methodology to construct a general dynamic simulation model and establish an experimental platform for scenario analysis of the financial sustainability of the social security system in Turkey, a country with severe population aging [12]. CiprianPanzaru (2015) analyzed the impact of population decline, increased proportion of young people receiving higher education, increased immigration, and a large number of retirees on the social security system in Romania as a case study, and studied the sustainable development of the social security system [13]. Cipriani Giam Pietro and Fioroni Tamara (2019) examined the relationship between retirement, fertility rate, and pension benefits using a three-period overlapping generations model and analyzed the impact of population changes on the pay-as-you-go pension system funded by a fixed contribution plan [14]. Xian Wei, Jin Cheng, Han Bing, Xu Xueying, Zhang Lu, Liu Hongbo (2021) drew lessons from foreign experience and used the Northeast region of China as an example. They established panel data models for social security contributions, social security benefits, new participants, and previous participants, and tracked the changes in social security among different age groups, genders, and workplaces from 2011 to 2015. They explored the impact of social demographic characteristics on the social security of resource-depleted cities, aiming to better guarantee the lives of the elderly in resource-depleted cities and improve their quality of life [15]. These research findings provide valuable references for studying and analyzing the coordination between population development and social security in China.

Although China started establishing its social security system only in 1949, which was more than 300 years later than the United Kingdom, the country has never ceased to explore reforms in the social security system. The academic community in China has conducted numerous theoretical studies on the relationship between social security and population aging. Some representative studies include Wang Jinying and Liang Junxiang (2008), who discuss the balance between declining fertility rates, insufficient supply of human capital and productivity, and pension security based on the challenges faced by future population development [16]. Their aim is to address the contradiction between population aging and the supply and demand of social security resources. Li Linlin (2013) constructs a population prediction model based on theories of demography, economics, and social security. This study explores the trends and analyzes the issues in the age structure, quantity, and composition of the elderly population in China in the foreseeable future. It also delves into the factors contributing to population aging from the perspective of labor supply and demand, analyzing their impact on the social security system [17], providing theoretical foundations for improving China's social security system. Liu Lüji, Li Qiao, and Zhang Xindan (2014) employ panel models to analyze the impact of changes in China's population structure from 1998 to 2012 on fiscal and social security expenditures. The study utilizes fixed effects and System Generalized Method of Moments (SYS-GMM) estimation methods, and conducts empirical analysis on the elderly dependency ratio and the child dependency ratio separately. The research concludes that improving the efficiency of fiscal allocation and increasing the level of fiscal social security expenditure can alleviate the pressure on fiscal social security expenditure [18]. Luo Wei and Cheng Peng (2022) employ a super-efficiency model to evaluate the economic growth efficiency of 31 provinces in China from 2010 to 2019. Additionally, using a truncated regression model for empirical analysis, the study investigates the impact of population aging and social security expenditures on economic growth efficiency. The research finds that appropriately increasing social security expenditures can effectively mitigate the impact of population aging on economic growth efficiency [19].

1.3.3. Literature evaluation

In conclusion, theoretical research on social security in China primarily focuses on fields such as sociology, economics, and political science, with relatively fewer discussions from a demographic perspective. Particularly, there is a significant lack of comprehensive and systematic studies on the relationship between population development and social security development, and research on the population and social security issues in China is notably weak. Existing literature mainly explores the interaction and impact between population age structure, population mobility, and the level of social security, often overlooking the relationship between other population development indicators and social security. Moreover, scholars tend to focus more on the impact of population aging on social security, while relatively lacking research and analysis on the coordination between population development and

social security development. This represents a relatively new research direction with significant research value.

Therefore, based on the existing research achievements of domestic demographers and social security experts, this study aims to further contribute to the in-depth investigation of population and social security issues, thereby promoting the coordinated development of population and social security. The research focuses on the four major economic regions in Guangdong Province as the study objects, analyzing the coordination relationship between population development and social security development in Guangdong Province. Statistical methods are used to calculate the coupling degree between different variables and measure the degree of coordination between population development and social security development in Guangdong Province. At the same time, empirical research methods are employed to explain the differences in coordination degree among different regions [5], aiming to provide reliable data and theoretical basis for the Guangdong provincial government in formulating sustainable social security policies.

2. Model Design

2.1. Definition of the Study Object

Population development and social security have long been mutually reinforcing, and population structure is an important factor supporting the high-quality and sustainable development of national social security undertakings. If the level of social security in a region exceeds the level of population development, it will lead to excessive fiscal pressure, social unrest, and impact economic development. Therefore, the coordinated development of population in a region is the fundamental requirement for the sustainable development of local social security. Due to the simplicity, ease of calculation, and intuitive results of the coupling coordination degree model, this study constructs a system of related indicators for population development and social security and utilizes the concept of coordination coupling degree. It divides Guangdong Province into four major regions based on the current regional carrying capacity, existing development intensity, and development potential [20], and further divides them into four main regions. The four major regions in Guangdong Province mainly refer to the Pearl River Delta region in the middle and lower parts, including nine cities of Huizhou, Guangzhou, Dongguan, Shenzhen, Zhaoqing, Foshan, Zhongshan, Zhuhai, and Jiangmen. The mountainous region refers to five cities of Shaoguan, Qingyuan, Meizhou, Heyuan, and Yunfu. The western wing includes three cities of Zhanjiang, Maoming, and Yangjiang. The eastern wing includes four cities of Shantou, Chaozhou, Jieyang, and Shanwei^[21]. This study will use this regional division to measure the coordination degree between population development and social security development in Guangdong Province.

2.2. Data Source Description

This study designs an indicator system for measuring the coordination degree between population development and social security development based on principles of scientificity, comparability, purposiveness, and operability. The data primarily come from the "Guangdong Statistical Yearbook" and the "Statistical Bulletin of Guangdong Province Population Census." Due to the frequent outbreaks of the COVID-19 pandemic and the complex international situation during the years 2020-2022, population and economic policies in Guangdong Province have been significantly restricted. It has been challenging to obtain consistent and comprehensive statistical data from various prefecture-level cities. To ensure a comprehensive coverage of indicators and enhance the credibility of the data, the decision was made to utilize the relevant data collected from the seventh population census conducted by the Guangdong Provincial Government in 2020.

2.3. Determination of Evaluation Indicators

Population development is a highly complex and systematic project that directly relates to the great development of the Chinese nation. Population conditions represent the most basic and important national situation for a country. Population development involves not only quantitative changes and growth but also qualitative leaps and improvements. It can be said that population development is a unity of quantitative and qualitative changes. The system of population development and social security development comprises two major systems: the population development system and the social security system. Generally, the population development system is primarily composed of indicators related to

population quantity, age structure, urban-rural disparities, and educational attainment. The age structure of a population in a region can affect the development of social security. The higher the proportion of elderly population, the greater the financial crisis in the local social security funds, leading to a severe deficiency in the social security system. Additionally, the development of productivity in a region also requires a stable social environment and reasonable labor mobility. Excessive urban-rural disparities hinder the mobilization of farmers' enthusiasm. Moreover, the level of education also influences the choice of social security behavior among local residents. Regions with higher levels of educational attainment often have relatively higher rates of social security coverage. Social security has a significant impact on the population, and the state of social security directly affects people's lifestyles, consumption demands, and ideological consciousness. To reflect the comprehensive level of the social security system, this study selects three indicators: the level of social security expenditure, the level of social security coverage, and the level of social security benefits. The level of social security expenditure reflects the investment of economic development in social security. Economic development in a region is often inseparable from population development, as balanced population development contributes to improving the level of social security. Meanwhile, the coverage and benefits levels of social security can directly reflect the extent to which the local government ensures people's livelihood based on the population development situation. These indicators have a strong influence on the development of social security.

Table 1: Relevant indicators of the regional population development system and social security system in Guangdong Province

Target Level	System level	Guideline level	Weighting	Indicator level	Weighting
Coupled system of population development and social security	Regional Population Development System Indicators	Population profile	37.89%	X ₁₁	11.34%
				X ₁₂	1.94%
				X ₁₃	24.61%
		Age structure of the population	22.68%	X ₂₁	5.71%
				X ₂₂	12.89%
				X ₂₃	4.08%
		Urban-rural gap	17.10%	X ₃₁	15.70%
				X ₃₂	1.40%
		Education level	22.33%	X ₄₁	1.08%
				X ₄₂	3.24%
				X ₄₃	6.06%
				X ₄₄	11.95%
	Social security system indicators	Level of social security spending	3.61%	Y ₁₁	0.19%
				Y ₁₂	3.42%
		Level of social security coverage	78.86%	Y ₂₁	4.29%
				Y ₂₂	9.88%
				Y ₂₃	4.59%
				Y ₂₄	9.82%
				Y ₂₅	12.50%
				Y ₂₆	10.79%
		Social security treatment level	17.54%	Y ₂₇	13.64%
				Y ₂₈	13.35%
				Y ₃₁	4.29%
				Y ₃₂	3.39%
				Y ₃₃	4.44%
				Y ₃₄	5.42%

Note: X₁₁: Total resident population at the end of 2020 (in ten thousand people); X₁₂: Registered population at the end of 2020 (in ten thousand people); X₁₃: Number of registered population inflows at the end of 2020 (in people); X₂₁: Percentage of child and adolescent population (%); X₂₂: Percentage of youth and middle-aged population (%); X₂₃: Percentage of elderly population (%); X₃₁: Proportion of urban population to total resident population at the end of 2020 (%); X₃₂: Proportion of rural population to total resident population at the end of 2020 (%); X₄₁: Percentage of population with primary education (%); X₄₂: Percentage of population with junior high school education (%); X₄₃: Percentage of population with high school (including vocational school) education (%); X₄₄: Percentage of population with university (including college and above) education (%); Y₁₁: Per capita social security and employment expenditure in each region (RMB/person); Y₁₂: Proportion of social security and employment expenditure to fiscal expenditure in each region (%); Y₂₁: Number of participants in basic

pension insurance (in ten thousand people); Y_{22} : Collection income of basic pension insurance fund (in ten thousand RMB); Y_{23} : Number of participants in basic medical insurance and maternity insurance (in ten thousand people); Y_{24} : Collection income of basic medical insurance and maternity insurance fund (in ten thousand RMB); Y_{25} : Number of participants in work-related injury insurance (in ten thousand people); Y_{26} : Collection income of work-related injury insurance fund (in ten thousand RMB); Y_{27} : Number of participants in unemployment insurance (in ten thousand people); Y_{28} : Collection income of unemployment insurance fund (in ten thousand RMB); Y_{31} : Per capita pension in each region (RMB/person/year); Y_{32} : Per capita minimum living guarantee expenditure for urban and rural residents in each region (RMB/person); Y_{33} : Number of beds in medical and health institutions in each region (beds); Y_{34} : Number of healthcare technical personnel in each region (people).

In order to comprehensively evaluate the coordination relationship between population development and social security development in different regions of Guangdong province, this study referred to the indicator system proposed by Tan Wei and Wu Yongqiu in their paper "Comparison and Analysis of the Coordinated Development of Social Security and Economic Development"^[5]. The evaluation of the population development system was based on the following indicators for the year-end of 2020: total population of permanent residents, registered population, in-migration population, population of children and adolescents (0-14 years old), population of youth and middle-aged individuals (15-64 years old), population of elderly individuals (65 years old and above), the proportion of urban population to the total population of permanent residents, the proportion of rural population to the total population of permanent residents, the proportion of primary and secondary school education per 100,000 population, the proportion of junior high school education per 100,000 population, the proportion of high school (including technical secondary school) education per 100,000 population, and the proportion of university (including college and above) education per 100,000 population.

The evaluation of the social security system considered the following indicators for each region: per capita social security and employment expenditure, the proportion of social security and employment expenditure to fiscal expenditure, the number of participants and fund collection of basic pension insurance, the number of participants and fund collection of basic medical insurance and maternity insurance, the number of participants and fund collection of work injury insurance, the number of participants and fund collection of unemployment insurance, per capita pension amount, per capita minimum living guarantee expenditure for urban and rural residents, the number of hospital beds in healthcare institutions, and the number of healthcare technical personnel.

By considering the indicators from both the population development system and the social security system, a comprehensive evaluation of the coordinated and coupled system between population development and social security development was constructed (refer to Table 1).

2.4. Measurement Methods of Indicator Data

To eliminate the influence caused by the different scales of various types of data, this study initially employs the range method to "normalize" the data, compressing and transforming all data to fall within the range of [0.01, 0.99], while preserving their relative significance. If the original data does not fall between (0, 1), it can lead to the situation where the coupling coordination degree (D value) does not fall within the range of (0, 1), making it difficult to determine the level of coordination.

Firstly, it is necessary to distinguish the positive and negative effects of the evaluation indicators, i.e., whether a larger indicator value is better or worse for the overall system. Let the variable u_i ($i = 1, 2, \dots, n$) represent the comprehensive rank parameter of the i th subsystem in the target system, and x_{ij} ($j = 1, 2, \dots, n$) denote the j th indicator value of the comprehensive rank parameter of the i -th subsystem. The normalized value u_{ij}' represents the contribution of the variable to the efficiency of the subsystem and is bounded between [0.01, 0.99]. Here, b and a represent the upper and lower bounds, respectively, with values of 0.99 and 0.01. Max and Min represent the maximum and minimum values, respectively, corresponding to a certain indicator. Therefore, u_{ij}' can be expressed as:

$$u_{ij}' = \frac{a+(b-a)*(X_{ij}-Min_{(ij)})}{(Max_{(ij)}-Min_{(ij)})} \quad (1)$$

The weights of each indicator are assigned using the entropy method, which involves constructing a weight calculation table based on entropy values for each indicator. A smaller entropy value for an indicator indicates a higher amount of information captured by that indicator, resulting in a larger weight coefficient. This implies that the indicator has a greater impact on the overall evaluation. Subsequently, considering the meanings, importance, and fundamental nature represented by each

indicator, a comprehensive weighting is determined by balancing these factors. This approach avoids subjective weighting and minimizes the interference caused by subjective factors, ensuring scientific and effective results (see Table 2). Therefore, based on the weights of each indicator and the normalized data, the comprehensive levels of the population development system and the social security system are calculated by weighted summation.

$$u_i = \sum_{j=1}^m \omega_{ij} u'_{ij} \tag{2}$$

$$\sum_{j=1}^m \omega_{ij} = 1 \tag{3}$$

Where u_i represents the comprehensive level of population development or social security, and ω_{ij} represents the weight of each indicator.

Table 2: Weight coefficients of indicators in the population development system and social security system in Guangdong Province.

(Population Development System) Summary of results of entropy method to calculate weights				(Social Security System) Summary of results of entropy method to calculate weights			
item	Information entropy value e	Information utility value d	Weighting factor w	item	Information entropy value e	Information utility value d	Weighting factor w
X ₁	0.7804	0.2196	11.34%	Y ₁	0.9906	0.0094	0.19%
X ₂	0.9625	0.0375	1.94%	Y ₂	0.8289	0.1711	3.42%
X ₃	0.5237	0.4763	24.61%	Y ₃	0.7849	0.2151	4.29%
X ₄	0.8896	0.1104	5.71%	Y ₄	0.5054	0.4946	9.88%
X ₅	0.7506	0.2494	12.89%	Y ₅	0.7703	0.2297	4.59%
X ₆	0.921	0.079	4.08%	Y ₆	0.5082	0.4918	9.82%
X ₇	0.6961	0.3039	15.70%	Y ₇	0.3738	0.6262	12.50%
X ₈	0.9729	0.0271	1.40%	Y ₈	0.4596	0.5404	10.79%
X ₉	0.9792	0.0208	1.08%	Y ₉	0.3169	0.6831	13.64%
X ₁₀	0.9374	0.0626	3.24%	Y ₁₀	0.3316	0.6684	13.35%
X ₁₁	0.8827	0.1173	6.06%	Y ₁₁	0.7849	0.2151	4.29%
X ₁₂	0.7687	0.2313	11.95%	Y ₁₂	0.83	0.17	3.39%
				Y ₁₃	0.7779	0.2221	4.44%
				Y ₁₄	0.7286	0.2714	5.42%

Note: X1: Total resident population at the end of 2020 (in ten thousand people); X2: Registered population at the end of 2020 (in ten thousand people); X3: Number of registered population inflows at the end of 2020 (in people); X4: Percentage of child and adolescent population (%); X5: Percentage of youth and middle-aged population (%); X6: Percentage of elderly population (%); X7: Proportion of urban population to total resident population at the end of 2020 (%); X8: Proportion of rural population to total resident population at the end of 2020 (%); X9: Percentage of population with primary education (%); X10: Percentage of population with junior high school education (%); X11: Percentage of population with high school (including vocational school) education (%); X12: Percentage of population with university (including college and above) education (%); Y1: Per capita social security and employment expenditure in each region (RMB/person); Y2: Proportion of social security and employment expenditure to fiscal expenditure in each region (%); Y3: Number of participants in basic pension insurance (in ten thousand people); Y4: Collection income of basic pension insurance fund (in ten thousand RMB); Y5: Number of participants in basic medical insurance and maternity insurance (in ten thousand people); Y6: Collection income of basic medical insurance and maternity insurance fund (in ten thousand RMB); Y7: Number of participants in work-related injury insurance (in ten thousand people); Y8: Collection income of work-related injury insurance fund (in ten thousand RMB); Y9: Number of participants in unemployment insurance (in ten thousand people); Y10: Collection income of unemployment insurance fund (in ten thousand RMB); Y11: Per capita pension in each region (RMB/person/year); Y12: Per capita minimum living guarantee expenditure for urban and rural residents in each region (RMB/person); Y13: Number of beds in medical and health institutions in each region (beds); Y14: Number of healthcare technical personnel in each region (people).

2.5. Model Construction

Drawing upon the concept and principles of "coupling" in physics, this study establishes the coupling relationship between the population development and social security systems, defining the

phenomenon of mutual interaction and influence between them as "coupling of population development and social security development" [22]. An indicator is derived to measure the degree of coupling between the two variables:

$$C = \sqrt{\frac{u_1 * u_2}{(\frac{u_1 + u_2}{2})^2}} \tag{4}$$

$$T = \alpha * u_1 + \beta * u_2 \tag{5}$$

$$D = \sqrt{C * T} \tag{6}$$

In this context: C represents the coupling degree between population development and social security development. T denotes the comprehensive coordination index of population development and social security development. D reflects the contribution of the overall development level of both population and social security to the degree of coordination in population development and social security development. u_1 and u_2 are the composite level indices of population development and social security development, respectively. α and β are undetermined coefficients, taking into account the complementary and mutually supportive relationship between population development and social security development. In this study, α is assigned a value of 0.5, and β is assigned a value of 0.5. Additionally, to further evaluate and study the entire system using the degree of coordinated development, a uniform distribution function method is employed to classify the degree of coupling coordination based on the variation of numerical values. Please refer to Table 3 for the classification criteria of the degree of coupling coordination.

Table 3: Classification Criteria of Coupling Coordination Degree

Coupling coordination degree D value interval	Coordination level	Degree of coupling coordination
(0.0~0.1)	1	extreme disorder
[0.1~0.2)	2	Severe disorder
[0.2~0.3)	3	Moderate disorder
[0.3~0.4)	4	Mild disorder
[0.4~0.5)	5	On the verge of disorder
[0.5~0.6)	6	Barely coordinated
[0.6~0.7)	7	Primary Coordination
[0.7~0.8)	8	Intermediate Coordination
[0.8~0.9)	9	Good coordination
[0.9~1.0)	10	High quality coordination

3. Research Results Analysis

In the above-mentioned study, this paper processed the relevant data on the coordination degree between population development and social security levels in the four major economic regions of Guangdong Province. Next, based on the calculated results, this paper will analyze the coordination degree of population development and social security development in the four major economic regions of Guangdong Province.

3.1. Comprehensive Level of Population Development and Social Security Development in Guangdong Province's Regions

Since the reform and opening-up in the 1980s, Guangdong Province has achieved rapid development and has maintained a trend of sustained growth, relying on its unique geographical location and government policies. Today, Guangdong has become one of the provinces with the highest degree of economic development and the largest economic aggregate in the country, shouldering the responsibility of developing strategic emerging industries. However, with the socio-economic development of Guangdong, some underlying problems and contradictions have increasingly emerged, particularly evident in the significant imbalance in economic development within the province, characterized by a polarized pattern. In particular, there is a considerable development gap between the Pearl River Delta, the eastern and western regions, and the mountainous areas, indicating an imbalance in spatial structure.

Based on the calculation results of the comprehensive level of population development in each

economic region presented in Table 4, the regions are ranked as follows in descending order: Pearl River Delta (0.9500) > Mountainous Area (0.0970) > Eastern Wing (0.0774) > Western Wing (0.0533). It can be observed that the population development level in the Pearl River Delta region is significantly higher than in other regions. Most of the population in Guangdong Province is concentrated in the Pearl River Delta, while other economic regions, due to their poor geographical location and location conditions, weak economic foundations, and general lag in socio-economic development, often struggle to attract talent and lack sufficient endogenous driving force, leading to a certain degree of imbalance. Therefore, the population development in these regions is relatively backward.

Looking at the comprehensive level of social security development, its spatial distribution characteristics are similar to those of population development, also showing a polarized phenomenon. Clear regional differences result in uneven social security levels across the economic regions. According to the data in Table 4, the comprehensive level of social security development is ranked as follows: Pearl River Delta (0.9882) > Mountainous Area (0.0371) > Western Wing (0.0140) > Eastern Wing (0.0084). It is evident from the data that the social security level in the Pearl River Delta region is relatively high, with a more comprehensive social security system. On the other hand, the social security level in other regions is relatively backward and requires further efforts in the construction of the social security system.

By comparing and analyzing the comprehensive development levels of population and social security in the four major economic regions, it can be observed that the social security levels in the Mountainous Area, Western Wing, and Eastern Wing are significantly lower than their population development levels. This indicates that the majority of cities in these regions have lagging social security compared to their population development levels. In contrast, the Pearl River Delta region exhibits the opposite pattern, with higher social security levels than population development levels. Additionally, the Eastern Wing region has a slightly higher comprehensive level of population development compared to the Western Wing region, but the social security comprehensive level in the Western Wing region is slightly higher than that in the Eastern Wing region. The spatial distribution of social security levels in the two wings shows some mismatch with the population development levels. In areas with population lag, the social security level is not necessarily low, and vice versa.

Table 4: Comprehensive Levels of Population Development and Social Security Development in Various Regions of Guangdong Province.

	Comprehensive level of population development U1	Comprehensive level of social security development U2
Pearl River Delta region	0.9500	0.9882
Mountainous region	0.0970	0.0371
West Wing region	0.0533	0.0140
East Wing region	0.0774	0.0084

3.2. Comprehensive Level of Population Development and Social Security Development in Guangdong Province's Regions

Due to the imbalance of economic development, there are significant differences in the level of population development and varying levels of social security in different regions. In order to further clarify the spatial distribution patterns and characteristics of the coupling between population development and social security development in Guangdong Province, and reveal the regularity of regional population and social security coupling from a mechanistic perspective [22], this study focuses on the four major economic regions of Guangdong Province and conducts further research on the coupling between population development and social security development in 2020. By utilizing the coupling coordination degree model, the coupling coordination degrees of population development and social security development in the four major economic regions of Guangdong Province in 2020 are calculated, and a distribution map of the coupling coordination degrees of population development and social security development in Guangdong Province is presented (see Figure 1).

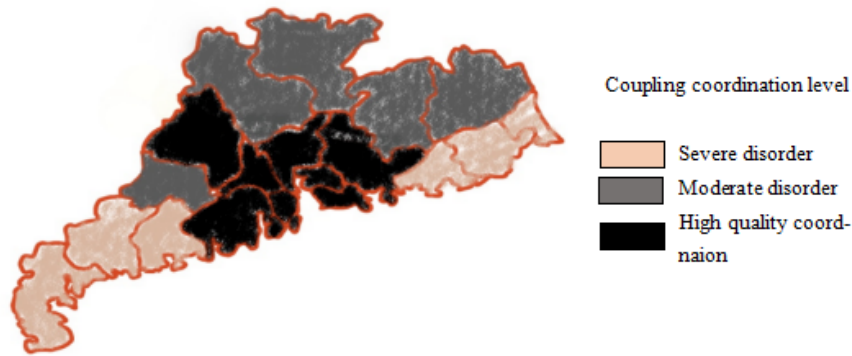


Figure 1: Distribution Map of Coupling Coordination Degree of Population Development and Social Security Development in Various Regions of Guangdong Province

From Figure 1, it can be observed that there are significant regional differences in the coupling coordination degree of population development and social security development in Guangdong Province. In terms of the coordination degree in each region, the Pearl River Delta region exhibits significantly higher coordination degree compared to the mountainous area, the western wing, and the eastern wing. The ranking of coordination indices is as follows: Pearl River Delta (0.9691), mountainous area (0.0670), western wing (0.0337), and eastern wing (0.0429). When considering the classification of coupling coordination degree in each region, the Pearl River Delta region falls under the category of high-quality coordination, while the mountainous area is classified as moderately imbalanced, and the western wing and the eastern wing are categorized as severely imbalanced. The distribution of coordination degree classifications shows a pattern of polarization (see Table 5).

Table 5: Calculation Results of Coupling Coordination Degree of Population Development and Social Security Development in Various Regions of Guangdong Province

Item	Coupling degree C-value	Coordination index T-value	Coupling coordination D-value	Coordination level	Degree of coupling coordination
Pearl River Delta	0.9998	0.9691	0.9843	10	High quality coordination
Mountainous areas	0.8950	0.0670	0.2450	3	Moderate disorder
West Wing	0.8109	0.0337	0.1652	2	Severe disorder
East Wing	0.5944	0.0429	0.1597	2	Severe disorder

Overall, the Pearl River Delta region is the most economically developed region in Guangdong Province, and its economic growth has also led to rapid population growth in the area. With economic development, the pace of social security reform in the region has been the fastest, particularly in the area of pension insurance, where it has reached a relatively mature stage. On the other hand, the other three economic regions in Guangdong Province have relatively lower levels of economic output, higher per capita social security and employment expenditures, and a majority of the employed population concentrated in government departments [22]. This has resulted in significant fiscal pressures, and as a result, the social security systems in these three economic regions are still incomplete. This development trend exacerbates the contradictions in coordinated development among regions and further contributes to the lag in the social security system.

4. Questions and Recommendations

4.1. Analysis of Differences in Coupling Coordination Degree among Regions in Guangdong Province

By analyzing the data on the coordination degree between population development and social security levels in the four major economic regions of Guangdong Province, significant spatial differences in the coupling coordination degree between regions are observed. What factors contribute to the differences in coupling coordination degree among the regions in Guangdong Province? The following empirical research methods will be employed to analyze the evident regional differences in

the coupling coordination degree between population development and social security development in Guangdong Province ^[5].

4.1.1. Geographic Disparities

Geographic disparities in Guangdong Province have had a significant impact on the regional economy and, to some extent, have led to imbalances in population distribution and severe mismatches in social security.

The Pearl River Delta region, characterized by its flat terrain and low elevation, is highly suitable for urban development and expansion. The region is abundant in water systems and enjoys ample water flow, facilitating a well-developed inland waterway transportation system. With convenient land and sea transportation, the region possesses inherent advantages. Additionally, the Pearl River Delta is located in the economic hinterland of Guangdong Province, adjacent to Hong Kong and Macau, which facilitates the introduction of advanced management practices and the expansion of international communication platforms. This promotes collaboration within the region, enhances the region's openness, and fosters a pattern of complementary industrial advantages. Moreover, being adjacent to the coastal areas of Southeast Asia, the Pearl River Delta is well-positioned for foreign trade and investment, providing favorable conditions for international trade circulation. These advantages and conveniences have accelerated the flow of resources such as capital, talent, and technology in the Pearl River Delta across regional boundaries, driving industrial integration and development, and rapidly widening the gap between the region and the Eastern Wing, Western Wing, and mountainous areas. Conversely, the Eastern Wing, Western Wing, and mountainous areas face relative disadvantages due to their inadequate natural conditions. The Eastern Wing region is mostly comprised of mountainous and hilly areas, distributed in valleys and basins. The Western Wing region is predominantly mountainous, with plains and mountainous terrain interspersed only along the coastal areas. The mountainous areas consist predominantly of mountainous terrain. Such geographic environments create transportation difficulties, which naturally limit economic development. Moreover, these areas are prone to frequent natural disasters. In 2022, Guangdong experienced heavy rainfall, resulting in landslides and flooding in the mountainous areas, causing hundreds of thousands of people to be affected and an economic loss of nearly 1.8 billion RMB.

Due to its geographic advantages and rapid development, the Pearl River Delta region has continuously expanded its economic scale and exerted a suction effect on the surrounding areas in terms of population and economy. This has attracted a large influx of labor from other parts of the province to the Pearl River Delta region, with population growth driving the development of social security. As a result, the social security development in the Pearl River Delta region has progressed relatively comprehensively and rapidly. In contrast, the Eastern Wing, Western Wing, and mountainous areas have limited population mobility due to inconvenient transportation, resulting in relatively slow population growth. Consequently, the economy in these areas is significantly constrained, leading to a corresponding lag in the development of social security.

4.1.2. Inappropriate Policy Guidance

During the development process, inadequate policy guidance from local governments in Guangdong Province regarding population development and social security has resulted in different patterns and speeds of development across regions. Some areas have experienced rapid development but with insufficient levels of social security, while others have high levels of social security but lag behind in population development.

In this situation, the regional development policies of the Guangdong provincial government have long favored the Pearl River Delta region. Investments in infrastructure, industry support, and fiscal transfers have been significantly biased towards the developed areas. This has resulted in a relatively deteriorated development environment in the Eastern Wing, Western Wing, and mountainous areas, making it difficult for these regions to synchronize their development with the Pearl River Delta. The existing industrial policies have also failed to facilitate the rational flow of industrial elements to the Eastern Wing, Western Wing, and mountainous areas. As a consequence, high-tech industries and industries with high added value have excessively concentrated in the Pearl River Delta region, while the industrial structure in non-Pearl River Delta areas lags behind, further widening the regional development gap. Moreover, the policy orientation of the Guangdong provincial government in urbanization, basic education, higher education, and technological innovation also tends to support the Pearl River Delta region. This results in the concentration of population dividends and innovative resources in that region, exacerbating the severe imbalance in population development and social security development between regions.

4.1.3. Disparities in Urbanization Development

As one of China's largest economic provinces, Guangdong Province has a relatively high overall level of urbanization. According to data released by the National Bureau of Statistics of China, as of 2020, the urbanization rate in Guangdong Province had reached 74.4%, with the urbanization rate in the Pearl River Delta region as high as 87.5%. However, there are significant disparities in urbanization development levels across different regions, resulting in uneven population distribution and significant differences in social security development.

Relatively speaking, the urban planning in the Eastern Wing, Western Wing, and mountainous areas exhibits unreasonable aspects. There is insufficient management of population mobility, and public service facilities are not adequately developed, leading to a lag in urbanization, inadequate attractiveness, and lower population and social security levels. On the other hand, the Pearl River Delta region is the economic core of Guangdong Province. The region offers high employment opportunities and income levels, attracting a large influx of population. As a result, other regions have lower employment rates, and the population in these areas consists mainly of migrant workers, leading to lower levels of social security^[23].

In summary, the imbalance between population development and social security development across different regions in Guangdong Province is the long-term result of factors such as geography, policies, and urbanization development. To achieve coordinated development among regions, it is necessary to strengthen overall coordination and improve the supporting facilities of public services between regions. This includes refining regional development strategic planning, enhancing government policy guidance, optimizing factor allocation, establishing social security systems and policies that align with the actual situation, and improving the level of economic development in each region, in order to achieve comprehensive, coordinated, and sustainable development.

4.2. Policy Recommendations

In the preceding sections, this paper has analyzed the research results and reasons for the coordination level between population development and social security development in different regions of Guangdong Province. In the following, based on the actual situation in Guangdong Province, this paper will propose some recommendations with the aim of improving the coordination level of population development and social security development between regions, promoting coordinated regional development in Guangdong Province, enhancing the level of social security, and attracting more talent to settle in Guangdong.

4.2.1. Strengthen Infrastructure Construction to Narrow the Geographic Disparity Gap

Although the geographic disparities between regions in Guangdong Province have to some extent led to imbalanced population distribution and significant mismatches in social security, we can narrow the geographic disparity gap and alleviate the problem of excessive population concentration by strengthening the construction of public infrastructure and improving the production and living environment. This, in turn, will promote the coordination between population development and social security development among regions.

In different regions of Guangdong Province, the development level of public transportation facilities varies. To alleviate the problem of excessive population concentration, it is advisable to enhance the construction of public transportation facilities and increase the coverage of urban rail transit, bus routes, expressways, and other transportation facilities to facilitate people's travel. Additionally, the construction of cultural and sports facilities can promote the improvement of cultural literacy among the population. Providing more cultural and sports venues and facilities to the people can also alleviate the problem of excessive population concentration and promote balanced regional development.

Of course, healthcare facilities are crucial for ensuring people's health. To safeguard the health of the population, the government can strengthen the construction of public healthcare facilities, establish and improve public health service facilities such as hospitals, clinics, and health stations, expand the coverage of medical services, and enhance the quality of medical services. Establishing more community health service stations and medical centers, and establishing and improving the public medical insurance system, can meet the growing healthcare needs of the population, allowing people to enjoy high-quality and comprehensive healthcare facilities.

The government can increase investment in infrastructure, intensify efforts in environmental

pollution control, urban greening, and waste management, and strengthen the governance and protection of the production and living environment. These measures will improve the living environment, enhance the level of transportation, cultural and sports facilities, medical and healthcare facilities, and promote the coordinated development of different regions. This will enhance people's identification with the region's living environment, improve the quality of production and living, help control population mobility, increase residents' satisfaction with the region they reside in, and enhance the overall comprehensive strength of the region.

4.2.2. Leveraging Government Leadership to Promote Regional Coordinated Development

The Guangdong provincial government should actively play a guiding role, fully leveraging regional advantages, and considering the specific circumstances of each region. It should increase investment in social security, establish and improve social security systems, and enhance the level of social security, forming a comprehensive social security system covering the entire province. At the same time, the government should also strengthen the promotion of social security awareness, improve people's understanding and awareness of social security policies, and ensure that everyone has access to basic social security rights. While enhancing people's awareness of social security, government departments should also strengthen social security supervision, improve the social security service system, and establish sound supervision and institutional guarantee mechanisms to ensure the compliant, transparent, and efficient use of social security funds and improve the management efficiency and quality of social security.

In addition, the Guangdong provincial government should support and guide small and medium-sized enterprises (SMEs) through methods such as industrial transformation and upgrading and resource sharing. It should continue to promote regional coordinated development, encourage innovation and technological development, establish and improve innovation support systems such as innovation incubators and technology transfer institutions, and facilitate the transformation and upgrading of the economy from traditional industries to high-tech industries. Strong support should be provided to the development of high-tech industries, cultural and creative industries, green and environmental protection industries, and other tangible economic sectors to increase Guangdong Province's economic strength, promote the complementary and coordinated development of industries in various regions, generate more employment opportunities, increase wealth, improve people's basic living conditions and social security, and promote the coordination between population development and social security development among regions.

4.2.3. Strengthening Urban-Rural Integration to Alleviate Disparities in Urbanization Development

There are significant disparities in the level of urbanization development among different regions in Guangdong Province, leading to uneven population migration and severe imbalances in social security development in various areas.

The Guangdong provincial government should strengthen urban-rural integration, promote complementary economic development between urban and rural areas, and enhance the development level of rural areas to achieve more coordinated urban-rural development^[24]. Specific measures include: creating an open, innovative, trustworthy, and rule-of-law talent service environment through government and social organization efforts; strengthening cultural construction and promoting multicultural exchanges; improving the quality of life and happiness index of talents; and providing better public service facilities such as housing, education, healthcare, and transportation for talents. Moreover, policies should be tailored to the specific circumstances of each region, with the focus on exploring, attracting, cultivating, and retaining talents to enhance economic development and social security levels.

Additionally, the government should establish and improve mechanisms for urban-rural economic linkage, promoting mutual complementarity and cooperation between cities and rural areas to facilitate coordinated economic development. Efforts should be made to enhance the labor quality in rural areas, cultivate entrepreneurial spirit among farmers, improve their production and vocational skills, and facilitate talent mobility between urban and rural areas to balance the job market. Furthermore, the government should strengthen the construction of social security systems, ensuring equal access to social security between urban and rural residents, improving the social security level of farmers, narrowing the urban-rural social security gap, and providing support and protection for population development through the social security system. These actions can also attract talents, enhance the region's soft power, reduce social instability factors, and encourage more young people to settle in the area.

In summary, the Guangdong provincial government should formulate corresponding policies to actively guide regional economic integration while strengthening the construction of public infrastructure and social security systems. By promoting urban-rural integration, fostering complementary economic development, narrowing the wealth gap between regions, and coordinating the population development and social security levels in various areas, the government can maintain the coordinated development of different regions, further promote economic development in Guangdong Province, and attract more talents to settle in Guangdong.

5. Conclusions

By constructing an evaluation index system and a coupling coordination model, the coordination between population development and social security development in Guangdong Province was studied from a spatial distribution perspective. The following findings were observed: Firstly, there is a significant positive correlation between the level of population development and social security development in most regions. Regions with higher levels of population development also tend to have relatively higher levels of social security. The spatial distribution patterns of the two factors exhibit a high degree of similarity, with significant imbalances in development between regions. Secondly, in terms of the level of coordination between population development and social security development, only the Pearl River Delta region can be considered as having a high level of coordination, while most regions still experience serious imbalances in their coupling coordination. Over the long term, the imbalance between population development and social security systems can hinder sustainable and stable economic development. Analyzing the spatial distribution of population development and social security development levels in Guangdong Province, as well as the evolving relationship between the two, can help the various economic regions of Guangdong Province understand the objective laws of their own development and provide valuable insights for promoting coordinated population development and social security. However, this study has not yet analyzed the mechanisms underlying the relationship between population development and social security development, which requires further in-depth research.

There is a close connection between population development and social security. Overall, population development and social security interact and promote each other. Population development serves as the foundation for the emergence and development of social security systems, providing support for social security, while social security, in turn, promotes population development. The two must interact over the long term to ensure coordinated development. In recent years, the Guangdong provincial government has made great efforts to improve people's livelihoods, continuously enhance the level of social security, and increase social welfare expenditures, resulting in a continuous improvement in the coordination between population development and social security in Guangdong Province. This contributes to the sustained, healthy, and rapid development of the Guangdong economy. However, it is also important to recognize that there are still significant differences in both the level of population development and social security, as well as the degree of coordination between the two, among different regions. Therefore, the national government must further deepen social security system reforms, strengthen the construction of social security systems while promoting economic integration, narrow the wealth gap between regions in Guangdong Province, maintain the coordinated development of all regions, promote further economic development in Guangdong, and attract more talents to settle in the province, ensuring that all people can share the fruits of economic development.

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