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Empirical Study on How Industrial Structure in Shenzhen City Affects GDP

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Abstract

There is a close relationship between industrial structure and GDP. Based on the time series data of Shenzhen's GDP, GDP of the primary industry, GDP of the industrial sector, GDP of the construction industry, and GDP of the tertiary industry from 1979 to 2022, an empirical analysis of the relationship between GDP and industrial structure was conducted. In the analysis, methods such as unit root test, cointegration analysis, multicollinearity test, sequence correlation test, and correction were used. The empirical results show that:

At a significance level of 5%, the explanatory variables, including the logarithm of the first industry GDP (lnX1), the logarithm of the industrial GDP (lnX21), the logarithm of the construction industry GDP (lnX22), and the logarithm of the third industry GDP (lnX3), have a significant impact on the logarithm of the dependent variable, the GDP of Shenzhen (lnGDP). On average, a 1% increase in the first industry GDP is associated with a 0.051% increase in the GDP of Shenzhen, while a 1% increase in industrial GDP, construction industry GDP, and third industry GDP is associated with a 0.159%, 0.162%, and 0.621% increase in the GDP of Shenzhen, respectively.

To account for this correlation, a lag of two periods, or two years, is necessary. The first year lag has a positive impact on the GDP, while the second year lag has a negative impact.

Based on the above findings, the following policy recommendations are proposed.

Keywords: *Shenzhen City, industrial structure, GDP, time series data, cointegration analysis.*

1. Introduction

1.1. Research Background and Significance

As a representative city of China's Special Economic Zones, the industrial structure of Shenzhen has significant implications for GDP. The transformation of Shenzhen's industrial structure from traditional manufacturing to high-tech industries is of great importance for the city's economic development and sustainability.

Firstly, studying the impact of Shenzhen's industrial structure on GDP can help the local government and relevant departments understand the influence of industrial structure adjustment on economic growth. As a Special Economic Zone, Shenzhen has been actively promoting the transformation and upgrading of its industrial structure. By studying the impact of industrial structure on GDP, the contribution of different industries to economic growth can be evaluated, providing a basis for the government to formulate more effective industrial policies and development strategies. For example, if a high-tech industry contributes significantly to GDP, the government can further increase support for that industry to promote economic growth.

Secondly, studying the impact of Shenzhen's industrial structure on GDP can provide reference for other cities. With the transformation and upgrading of China's economy, many cities are undergoing industrial structure adjustments, hoping to achieve economic growth and sustainable development through optimizing their industrial structure. Shenzhen, as a successful case, has important reference value for other cities in terms of its experience and lessons learned. By studying the impact of Shenzhen's industrial structure on GDP, other cities can learn from it and better adjust their industrial structure to achieve economic transformation.

Finally, empirical research on the impact of Shenzhen's industrial structure on GDP can reveal the effects and potential problems of industrial structure adjustments. Industrial structure adjustment is a complex process that may face various challenges and difficulties. By studying the impact of industrial structure on GDP, the effectiveness of industrial structure adjustments can be evaluated, and the development potential and problems of different industries can be understood. This is of great significance for optimizing industrial structure, improving economic efficiency, and achieving sustainable development. For example, if a certain industry has a low contribution to GDP, the government can further study its development bottlenecks and issues in order to formulate corresponding policies and measures to promote its development.

1.2. Objectives and Research Questions

The objective of this paper is to empirically study the impact of industrial structure on GDP in Shenzhen and propose corresponding policy recommendations. The research questions include the following aspects:

Firstly, the characteristics of Shenzhen's industrial structure: Study the characteristics of Shenzhen's industrial structure, including dominant industries, pillar industries, and emerging industries. Analyze the proportion and development trends of various industries in Shenzhen, and explore the evolution process of industrial structure and its impact on economic development.

Secondly, the relationship between industrial structure and GDP growth: Investigate the impact of Shenzhen's industrial structure on GDP growth. Analyze the contribution of different industries to GDP growth and study the influence of industrial structure adjustment on GDP growth. Establish an economic model to explore the potential mechanism of industrial structure adjustment on GDP growth.

Thirdly, the impact of industrial structure on economic efficiency: Analyze the impact of Shenzhen's industrial structure on economic efficiency. Study the influence of industrial structure on employment, income distribution, innovation capability, and international competitiveness. Evaluate the strengths and weaknesses of Shenzhen's industrial structure and provide a basis for industrial structure adjustment.

Fourthly, policy recommendations for industrial structure adjustment: Based on empirical research results, propose policy recommendations for industrial structure adjustment in Shenzhen. Provide policy suggestions for optimizing industrial structure, promoting industrial upgrading, and cultivating emerging industries. Promote the optimization and upgrading of Shenzhen's industrial structure and improve the quality and efficiency of economic development.

By studying the relationship between Shenzhen's industrial structure and GDP growth, scientific guidance and decision support can be provided for the city's industrial development and economic growth. At the same time, by analyzing the impact of industrial structure on economic efficiency, it can provide reference for the formulation of industrial policies in Shenzhen and promote sustainable economic development.

2. Literature Review

2.1. Research Status of Industrial Structure Abroad

In the 1850s and 1860s, Quinet proposed the division of social class structure, dividing it into the bourgeoisie, landowners, industrial capitalists, and workers. In the 1870s, Adam Smith published "The Wealth of Nations" and conducted in-depth research on the economy. With the success of the First and Second Industrial Revolutions, industrial development rapidly progressed after the mid-18th century, which also led to the development of the tertiary industry.

However, in the 1930s, the world experienced the Great Depression and economic recession, prompting people to rethink the distribution issues of capitalism. New Zealand economist Fisher first proposed the three-sector division method, which is of great significance for understanding economic structure and development. Japanese economist Akamatsu proposed the "flying geese" theory of industrial development, suggesting that late-developing countries can accelerate industrialization through the cycle of foreign imports, domestic production, and product exports.

In the 1940s, Kuznets published "National Income and Its Composition," in which he expounded on the relationship between national income and industrial structure and proposed the Kuznets industrial structure theory. According to this theory, most countries will not stop the trend of decreasing agricultural labor force.

These theories and viewpoints have important guiding significance for our understanding of changes in economic structure and development.

In the 1950s and 1960s, the theory of industrial structure further developed and researched. Some outstanding scholars proposed new viewpoints and theories, enriching the understanding of industrial structure.

American economist Harold Hotelling proposed the theory of "spatial economics," emphasizing the influence of geographical location on industrial structure. He believed that when choosing production locations, companies consider factors such as market demand, transportation costs, and the location of competitors, resulting in a spatial industrial layout.

American economist William Baumol proposed the "Baumol three-sector model," dividing economic activities into the production sector, service sector, and public sector. He believed that as the economy develops, the proportion of the service sector and public sector will gradually increase, while the proportion of the production sector will decrease.

In terms of international comparison of industrial structure, Japanese economist Hironobu Akamatsu proposed the "Akamatsu

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model," which explains how developing countries achieve industrialization through the cycle of foreign imports, domestic production, and product exports. He believed that developing countries can gradually improve their industrial level by imitating and absorbing the technology and experience of developed countries.

British economist Francis Cairncross explored the impact of industrial structure on economic growth and development in his work "The Economic Structure and Development." He believed that the interrelationships and interdependencies between different industries are important factors in determining economic structure and development direction.

In summary, the 1950s and 1960s were a period of rapid development of industrial structure theory, with scholars proposing many new viewpoints and theories, enriching the understanding of industrial structure. These theories have not only contributed to theoretical research but also provided important references for the formulation of practical industrial policies.

2.2. Research Status of Industrial Structure in China

The industrial structure refers to the proportion and composition of various sectors in the economy of a country or region. In China, there is a rich research status on industrial structure, mainly manifested in the following aspects:

Firstly, academic research: The academic and social science communities in China are very active in studying the industrial structure. Many scholars have conducted in-depth research on China's industrial structure from different perspectives and methods, including the evolution of industrial structure, optimization and adjustment of industrial structure, and the impact of industrial structure on economic growth.

Secondly, policy research: The Chinese government attaches great importance to the adjustment and optimization of industrial structure, and related policy research has also received widespread attention. Government agencies, think tanks, and research institutions often release policy research reports on industrial structure adjustment, providing references for government decision-making.

Thirdly, data support: China's statistical agencies provide rich industrial data, which provides important data support for industrial structure research. Researchers can analyze and utilize these data to gain a deeper understanding of the changes and characteristics of China's industrial structure.

Fourthly, regional research: There are significant differences in industrial structure among different regions in China, making regional research an important direction in the study of industrial structure. Many scholars have conducted in-depth research on the industrial structure of various regions in China, exploring the characteristics and development trends of different regional industrial structures.

2.3. Research on the Industrial Structure of Shenzhen

Zhou Changlin and Wei Jianliang (2007) studied the level of industrial structure in three cities: Shanghai, Shenzhen, and Ningbo. They found that Shanghai had the highest level, followed by Shenzhen, and Ningbo had the lowest level. They also believed that the level of industrial structure has a significant impact on economic development[1].

Dong Xiaoyuan (2012) conducted a theoretical and empirical study on the industrial structure adjustment in Shenzhen. Corresponding adjustment strategies were proposed and their effectiveness was verified through data analysis and model establishment[2].

Through the application of the Delphi method, Liu Hongdou and Ni Shiguang (2020) found a correlation between the discipline settings of higher education in Shenzhen and its industrial structure. They suggest aligning discipline settings with industry demands, enhancing interdisciplinary integration, and improving the research level of disciplines to promote the coordinated development of discipline settings and industrial structure in Shenzhen[3].

Gan Xing and Liu Chengkun (2018) found that based on data from 2001 to 2016 in Shenzhen, financial development has a positive impact on technological innovation and industrial structure optimization. Similarly, technological innovation also plays a positive role in industrial structure optimization. This has important policy implications for promoting regional economic development and industrial upgrading [4].

Zhao Ying's (2022) research found that foreign direct investment has had a positive impact on the industrial structure of Shenzhen, promoting industrial upgrading and transformation. By introducing advanced technology, management experience, and market channels, it has enhanced innovation capabilities and facilitated the development of related industries, while also increasing employment rates and economic growth[5].

Zhang Jiashan (2022) found that the opening of high-speed rail has significantly impacted the industrial structure of the Guangdong-Hong Kong-Macao Greater Bay Area, promoting collaborative development, optimizing layout, enhancing competitiveness and innovation capabilities, and driving cooperation and communication. This research has important reference value for industrial development and regional integration[6].

Shen Qi (2021) mainly analyzed the diversified industrial structure of foreign trade in the Guangdong-Hong Kong-Macao Greater Bay Area, including electronic products, machinery and equipment, chemical products, and other fields. The study also explored the challenges, opportunities, and development recommendations for the region in foreign trade[7].

A study conducted by Kong Yanling and Zhang Wenlong (2021) found that the industrial structure of the four major cities in the Guangdong-Hong Kong-Macao Greater Bay Area is undergoing a transformation towards modern service industries, but there are differences. In order to promote coordinated development, policy recommendations have been proposed[8].

Yuan Peng (2019) mainly discusses the industrial structure pattern of the Guangdong-Hong Kong-Macao Greater Bay Area and provides recommendations for its future deep integration and development, including optimizing the industrial structure, strengthening policy coordination, promoting innovation-driven development, and enhancing talent exchange[9].

Through empirical research on the industrial structure upgrading in Shenzhen, Zhang Qifu and Zhong Jian (2019) found that Shenzhen has achieved certain results in industrial structure upgrading, but there are still problems. They also proposed policy recommendations to promote further upgrading[10].

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2.4. **Relationship between Industrial Structure and Economy**

The research conducted by Hu Yan (2005) indicates that adjusting and optimizing the industrial structure in Shenzhen has a significant positive impact on economic growth. This implies that by changing the industrial structure, it is possible to drive rapid economic growth and enhance economic efficiency[11].

Zhong Wuya and Yan Wei (2012) studied the relationship between industrial structural changes and economic growth in Shenzhen Special Economic Zone. They found that the adjustment and optimization of industrial structure are crucial for economic growth, and proposed relevant policy recommendations[12].

Li Zhidi (2011) found that urbanization has a positive impact on economic growth, but a negative impact on industrial structure adjustment. On the other hand, industrial structure adjustment has a positive impact on economic growth, but urbanization has a negative impact on industrial structure adjustment. Therefore, it is necessary to consider these complex interactions comprehensively in policy making[13].

According to Qiu Jiangping's (2010) research, it is suggested that Shenzhen should adjust its industrial structure, develop innovative industries, strengthen the cultivation of innovation capabilities and technological innovation in order to promote economic growth. These policy recommendations have important guiding significance for the economic development of Shenzhen[14].

2.5. **The Relationship between Industrial Structure and Employment**

In her empirical analysis, Sang Lingling (2005) found that the evolution of China's industrial structure has a significant impact on the transformation of employment structure. The contribution of different industries to employment varies, and corresponding policy recommendations are proposed[15].

Zhang Yingli (2020) found that the industrial structure in Shenzhen is gradually shifting towards high-tech industries, with an increasing proportion of the service sector. This trend is also reflected in the employment structure, which has significant implications for economic development and employment prospects[16].

Liu Gege's (2017) research found that labor mobility has a positive impact on the adjustment of industrial structure in Shenzhen, promoting industrial optimization and upgrading[17].

A study conducted by Liu Guanzhan (2013) found a correlation between the changes in the population of non-registered residents in Shenzhen and the changes in industrial structure. The study proposes policy recommendations to promote the stable development of non-registered residents and optimize industrial structure adjustments[18].

2.6. **Evaluation of the Literature**

The above literature includes domestic and foreign scholars' research on industrial structure, which enriches the literature resources in the database and makes their due contributions in their respective research fields. In terms of methods, some literature mainly adopts descriptive methods, while others conduct empirical studies. However, in the literature that uses empirical methods, the time range of the data is relatively short, with the longest being only 16 years, and some even less than 10 years. In comparison, the data used in this paper covers a time span of 44 years from 1979 to 2022. Therefore, conducting empirical research on how the industrial structure affects GDP in Shenzhen has practical significance.

3. Analysis of the current situation of Shenzhen's GDP and industrial structure

3.1. **Shenzhen's GDP continues to grow.**

In 1979, the GDP of Shenzhen City was 19,638 million yuan, which was less than 2 billion yuan. Subsequently, the economy of Shenzhen City developed rapidly. In 1983, the GDP reached 131,212 million yuan, surpassing 1 billion yuan. In 1989, the GDP reached 1,156,565 million yuan, surpassing 10 billion yuan. In 1996, the GDP reached 10,484,421 million yuan, surpassing 100 billion yuan. In 2011, the GDP reached 119,228,085 million yuan, surpassing 1 trillion yuan. In 2016, the GDP reached 206,857,358 million yuan, surpassing 2 trillion yuan. In 2021, the GDP reached 306,648,538 million yuan, surpassing 3 trillion yuan. In 2022, the GDP reached 323,876,800 million yuan, which is 16,492 times the GDP in 1979. Over the 43-year period from 1979 to 2022, the GDP of Shenzhen City has continued to grow, as shown in Figure 1.

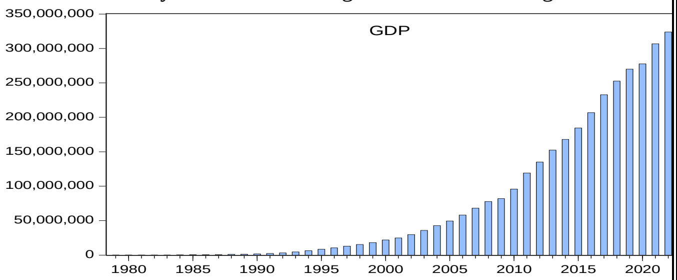

Figure 1: GDP of Shenzhen City from 1979 to 2022 (in thousands of yuan)

3.2. **The GDP of the tertiary industry in Shenzhen has also been continuously growing.**

From 1979 to 2022, the GDP of the tertiary industry in Shenzhen City has continued to grow. In 1979, the GDP of the tertiary industry was 83.48 million yuan, which was less than 100 million yuan. Subsequently, the GDP of the tertiary industry in Shenzhen City increased year by year. In 1980, it exceeded 100 million yuan, in 1984, it exceeded 1 billion yuan, in 1991, it exceeded 10 billion yuan, in 2000, it exceeded 100 billion yuan, and in 2015, it exceeded 1 trillion yuan. By 2022, the GDP of the tertiary industry in Shenzhen City is close to 2 trillion yuan, reaching 199,561.6 million yuan. This sustained growth trend can be seen from Figure 2

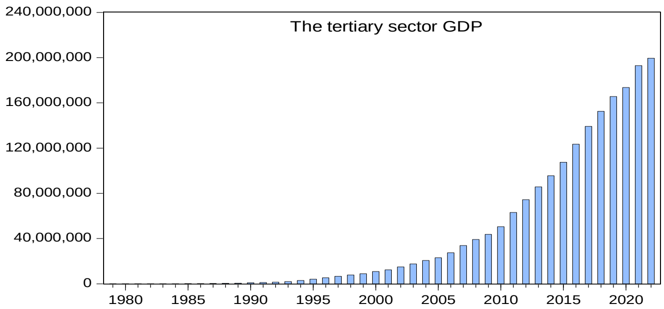

Figure 2: GDP of the tertiary industry in Shenzhen from 1979 to 2022 (in thousands of yuan)

3.3. **The industrial GDP and construction industry GDP in Shenzhen have experienced growth in the majority of years.**

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According to the information in Figure 3, the following conclusions can be drawn: From 1979 to 2022, both the industrial GDP and construction GDP of Shenzhen showed a growth trend. However, the growth of construction GDP was relatively slow, while the growth of industrial GDP in Shenzhen was relatively rapid.

In 2009, due to the impact of the US financial crisis, Shenzhen's industrial GDP slightly declined. And in 2020, due to the impact of the COVID-19 pandemic, Shenzhen's industrial GDP declined again. Except for these two years, Shenzhen's industrial GDP showed a growth trend in other years. From 2.313 million yuan in 1979 to 11,357.09 billion yuan in 2022, Shenzhen's industrial GDP has grown 49,100 times in the past 44 years.

Except for the years 1987 and 2005, when Shenzhen's construction GDP declined year-on-year, Shenzhen's construction GDP remained steadily growing in other years. In 1979, Shenzhen's construction GDP was 17.04 million yuan, and by 2022, this number had grown to 107.938 billion yuan, a growth of 6,333 times in the past 44 years.

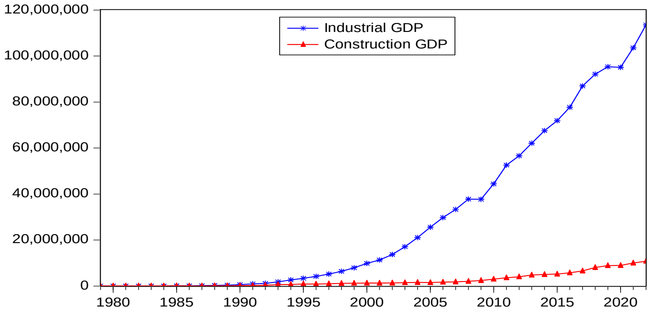

Figure 3: GDP of the industrial and construction sectors in Shenzhen, China from 1979 to 2022 (in thousands of yuan).

3.4. The GDP from the primary industry in Shenzhen has experienced fluctuating growth.

According to Figure 4, the volatility of Shenzhen's primary industry GDP is very evident. From 1979 to 1994, the primary industry GDP continued to grow for 16 years. However, starting from 1995, the primary industry GDP began to decline, showing negative growth for two consecutive years. Then, from 1998 to 1999, the primary industry GDP rebounded and continued to grow for two years. Subsequently, from 2000 to 2002, the primary industry GDP grew continuously for three years. However, from 2003 to 2007, the primary industry GDP declined for five consecutive years. From 2009 to 2012, the primary industry GDP once again declined for four years. Finally, from 2014 to 2021, the primary industry GDP grew continuously for eight years. However, starting from 2022, the primary industry GDP has shown a downward trend.

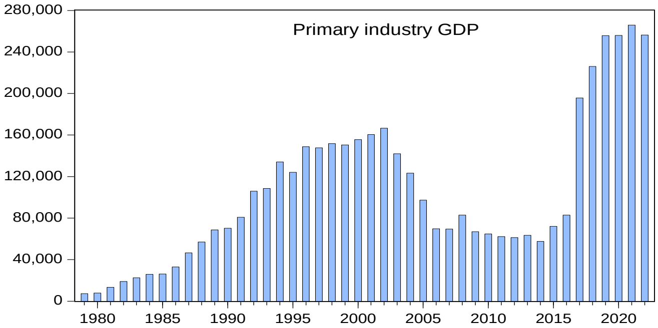

Figure 4: GDP of the primary industry in Shenzhen from 1979 to 2022 (in thousands of yuan)

3.5. The industrial structure of Shenzhen is continuously adjusting and optimizing.

According to the information in Figure 5, it can be concluded that the proportion of Shenzhen's primary industry GDP has significantly decreased. The proportion of industrial GDP initially increased and then decreased. The changes in the proportion of construction industry GDP showed a "two-rise, two-fall" pattern. The proportion of tertiary industry GDP exhibited a fluctuating upward trend. In summary, the industrial structure of Shenzhen is continuously being optimized.

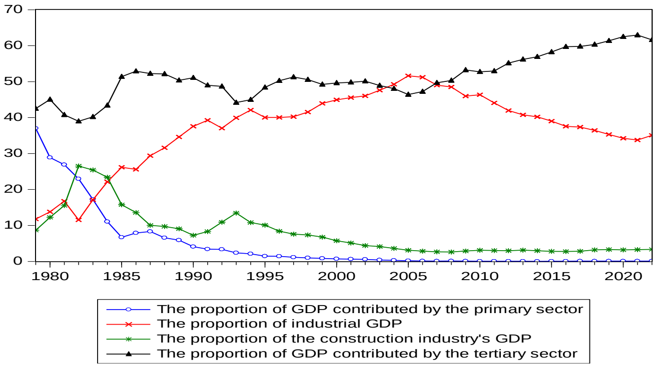

Figure 5: Changes in the industrial structure of Shenzhen City from 1979 to 2022 (Percentage)

3.5.1. The proportion of GDP from the primary industry has significantly decreased

From 1979 to 2022, the proportion of GDP contributed by the primary industry has experienced a significant decline. In the six-year period from 1979 to 1985, the proportion dropped sharply from 37.035% to 6.691%. However, in 1986 and 1987, there was a rebound in the proportion, reaching 7.902% and 8.322% respectively. From 1986 to 2007, the proportion continued to slowly decline, dropping from 8.322% to 0.102%. In 2008, the proportion stopped declining and remained stable. However, from 2009 to 2014, the proportion continued to slowly decrease. And in the five-year period from 2015 to 2019, the proportion slowly increased again. Finally, in the three-year period from 2020 to 2022, the proportion once again slowly declined. Overall, over the past 44 years, the proportion of GDP contributed by the primary industry has decreased by over 36%.

3.5.2. The proportion of industrial GDP initially increases and then decreases

The proportion of industrial GDP has shown different trends at different stages. From 1979 to 2005, the proportion of industrial GDP experienced an upward phase, increasing from 11.778% to 51.625%. However, from 2006 to 2022, the proportion of industrial GDP has shown a downward trend, with the exception of 2010 and 2022, where the proportion increased compared to the previous year. In all other years, the proportion has decreased compared to the previous year, declining from 51.217% in 2006 to 35.066% in 2022.

3.5.3. The proportion of GDP in the construction industry has shown a "two rises and two falls" pattern

During the period from 1979 to 1982, the proportion of GDP in the construction industry experienced rapid growth, rising from 8.677% in 1979 to 26.521% in 1982. Then, from 1983 to 1990, the proportion rapidly declined, dropping from 25.441% in 1983 to 7.245% in 1990. Subsequently, from 1991 to 1993, the proportion continued to rise for three consecutive years, reaching 13.464% in

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1993. From 1994 to 2008, the proportion continued to decline, falling from 10.819% in 1994 to 2.614% in 2008. Finally, from 2009 to 2022, the proportion fluctuated around 3%.

3.5.4. The proportion of GDP contributed by the tertiary industry exhibits a characteristic of fluctuating upward trend

Between 1979 and 1985, the GDP share of the tertiary sector fluctuated between 38% and 45%. Subsequently, from 1985 to 2007, this share fluctuated between 44% and 53%. In the period from 2008 to 2022, the share fluctuated between 50% and 63%. Over this span of 44 years, the largest amplitude exceeded 22%.

4. Data Source and Variable Labeling

4.1. Data Source

The data for Shenzhen's GDP, primary industry GDP, industrial GDP, construction industry GDP, and tertiary industry GDP from 1979 to 2021 for a total of 43 years are sourced from the "Shenzhen Statistical Yearbook 2022". The data for these five aspects in 2022 are sourced from the "Shenzhen Statistical Monthly Report (December 2022)".

4.2. Variable Labeling

For ease of modeling, the gross domestic product of Shenzhen is labeled as GDP, Shenzhen's primary industry GDP is labeled as X1, Shenzhen's industrial GDP is labeled as X21, Shenzhen's construction industry GDP is labeled as X22, and Shenzhen's tertiary industry GDP is labeled as X3. The natural logarithm of these variables is labeled as lnGDP, lnX1, lnX21, lnX22, and lnX3.

5. Empirical Research

5.1. Unit Root Test

To ensure the reliability of the regression analysis and avoid the occurrence of "spurious regression," it is crucial to conduct stationarity tests on the variables. In this study, we have opted to employ the Augmented Dickey-Fuller test (ADF test) for assessing stationarity. The outcomes of the ADF test are presented in Table 1.

Table 1 ADF Test Results for Variables

Testing variables	Type verification (C,T,K)	ADF statistic	Critical values of ADF at a significant level			D.W value	P-value	Test results
			1%	5%	10%			
GDP	(C,0,0)	10.2109	-3.59246	-2.93140	-2.60394	1.4147	1.0000	unstable
lnGDP	(C,0,0)	-10.7401	-3.59246	-2.93140	-2.60394	1.9098	0.0000	stable*
ΔlnGDP	(C,T,0)	-5.53111	-4.19234	-3.52079	-3.19128	1.6460	0.0002	stable*
X1	(C,0,2)	-1.85239	-3.60099	-2.93500	-2.60584	1.9371	0.3508	unstable
lnX1	(0,0,0)	2.42049	-2.61985	-1.94869	-1.61204	1.2878	0.9956	unstable
ΔlnX1	(0,0,0)	-4.00976	-2.62119	-1.94889	-1.61193	2.0991	0.0002	stable*
X21	(C,0,0)	7.05754	-3.59246	-2.93140	-2.60394	1.4374	1.0000	unstable
lnX21	(C,0,9)	-4.64843	-3.63941	-2.95113	-2.61430	2.0195	0.0007	stable*
ΔlnX21	(0,0,4)	-4.11784	-2.62724	-1.94986	-1.61147	2.3419	0.0001	stable*
X22	(0,0,0)	9.81822	-2.61985	-1.94869	-1.61204	1.7474	1.0000	unstable
lnX22	(C,T,1)	-3.72145	-4.19234	-3.52079	-3.19128	1.9032	0.0317	stable#
ΔlnX22	(0,0,0)	-2.58691	-2.62119	-1.94889	-1.61193	2.1688	0.0109	stable#
X3	(0,0,5)	-5.12686	-2.62724	-1.94986	-1.61147	2.0833	0.0000	stable*
lnX3	(C,0,0)	-9.61035	-3.59246	-2.93140	-2.60394	1.8535	0.0000	stable*
ΔlnX3	(C,T,0)	-5.22694	-4.19234	-3.52079	-3.19128	1.9010	0.0006	stable*

Note: (C, T, K) represents the constant term, trend term, and lag order used in the test; P-value represents the probability of accepting the null hypothesis. Δ represents first-order difference. *, #, & represent the ADF critical values at the 1%, 5%, and 10% confidence levels.

Based on the test results in Table 1, it can be observed that the original series GDP, X1, X21, and X22 are all found to be non-stationary in their respective test forms at a significance level of 5%. However, X3 is found to be stable. In the logarithmic sequence, only lnX1 is found to be non-stationary, while lnGDP, lnX21, lnX22, and lnx3 are all found to be stationary under their respective test forms and corresponding significance levels. Furthermore, when considering the first-order difference sequence of logarithms ΔlnX1, ΔlnX21, ΔlnX22, and Δlnx3, it can be observed that all of them are found to be stationary in their respective test forms at a significance level of 1%.

5.2. Model Construction

According to the conditions of cointegration modeling, if the dependent variable (lnGDP) and the explanatory variables (lnX1, lnX21, lnX22, and lnX3) have the same order of stationarity (first-order integrated series), then cointegration can be used for modeling. Therefore, lnGDP is chosen as the dependent variable and lnX1, lnX21, lnX22, and lnX3 are chosen as the explanatory variables. The cointegration model, referred to as Model 1, is constructed as follows:

$$lnGDP=\beta_0+\beta_1 lnX1+\beta_2 lnX21+\beta_3 lnX22+\beta_4 lnX3+\varepsilon \quad \ldots\ldots\ldots(1)$$

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In the given model, β_0 represents the constant term, β1-β5 are the estimated parameters. The variables lnGDP, lnX1, lnX21, lnX22, and lnX3 represent the natural logarithm of Shenzhen's GDP, the logarithm of the GDP of the primary industry, industrial sector, construction industry, and tertiary industry in Shenzhen, respectively. The random disturbance term ε represents the sum of all factors not included in the model. This alternative phrasing is used to avoid repetition.

5.3. E-G cointegration test

Apply the E-G two-step approach to conduct a cointegration test.

In the first step, estimate the parameters of the model. Use the method of least squares estimation and the data of Shenzhen's GDP, primary industry GDP, industrial GDP, construction industry GDP, and tertiary industry GDP from 1979 to 2022 to estimate the parameters of the cointegration model.as shown in cointegration model (2).

$lnGDP=1.727509-0.057383lnX_1+ 0.179396lnX_{21}+ 0.082748lnX_{22}+ 0.727614lnX_3$………(2)

T= (10.9187) (-2.87635) (5.40865) (2.62445) (18.1999)

R^2= 0.999649，F= 27758.19，DW= 0.474983，N=44。

Step 2: Perform a stationarity test on the residual sequence. Extract the residuals from the equation mentioned above and label them as "e". The outcomes of the ADF unit root test conducted on the residuals "e" are presented in Table 3.

Table 2 ADF unit root test for residuals

Testing variables	Type verification	ADF statistic	Critical values of ADF at a significant level			D.W value	P-value	Test results
	(C,T,K)		1%	5%	10%			
e	(0,0,0)	-2.78758	-2.61985	-1.94869	-1.61204	1.35623	0.0064	stable*

Note: In the (C, T, K) test, C represents the constant term, T represents the trend term, and K represents the lag order used in the test. The P-value represents the probability of accepting the null hypothesis. The ADF critical values at the 1% confidence level are denoted by *.

According to the results in Table 2, the critical value at the 1% significance level is higher than the ADF statistic value. Additionally, the p-value is less than 1%. Based on these findings, we can conclude that the residual sequence e is stationary at the 1% significance level. This implies that the explanatory variable lnGDP has a long-term stable relationship with the explanatory variables lnX1, lnX21, lnX22, and lnX3, successfully passing the cointegration test.

5.4. Multicollinearity Test

The T-statistics for lnX1, lnX21, lnX22, and lnX3 in the cointegration model (2) are -2.87635, 5.40865, 2.62445, and 18.1999, respectively. These values are greater than 2 in absolute terms, indicating that these variables are statistically significant at a 5% significance level. Additionally, the F-statistic of 739.4338 suggests that the cointegration model (2) is significant as a whole. This implies that there is no multicollinearity issue in the cointegration equation.

5.5. Testing and Correction of Sequence Correlation

5.5.1. Testing for sequence correlation

Based on the given information, the Durbin-Watson (DW) statistic is 0.474983, suggesting the presence of first-order serial correlation. However, to confirm the presence of higher-order serial correlation, the Lagrange Multiplier (LM) test should be conducted. The results presented in Table 3 support the existence of higher-order serial correlation.

Table 3 Results of LM test

Obs*R-squared	25.27104	Prob.Chi-Square(2)	0.0000
Obs*R-squared	25.28135	Prob.Chi-Square(3)	0.0000
Obs*R-squared	25.63307	Prob.Chi-Square(4)	0.0000
Obs*R-squared	25.65508	Prob.Chi-Square(5)	0.0001
Obs*R-squared	27.08353	Prob.Chi-Square(6)	0.0001
Obs*R-squared	27.08532	Prob.Chi-Square(7)	0.0003
Obs*R-squared	27.94631	Prob.Chi-Square(8)	0.0005
Obs*R-squared	28.22911	Prob.Chi-Square(9)	0.0009
Obs*R-squared	28.23160	Prob.Chi-Square(10)	0.0017
Obs*R-squared	28.32424	Prob.Chi-Square(11)	0.0029
Obs*R-squared	28.96333	Prob.Chi-Square(12)	0.0040
Obs*R-squared	29.57092	Prob.Chi-Square(13)	0.0054

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Obs*R-squared	29.62509	Prob.Chi-Square(14)	0.0086
Obs*R-squared	30.04924	Prob.Chi-Square(15)	0.0117

Based on the information provided in Table 3, we can conclude that the model shows a significant 14th order autocorrelation at a significance level of 1%. However, the 15th order autocorrelation is not significant. Therefore, we can say that the model has a maximum 14th order autocorrelation at a significance level of 1%.

5.5.2. Correction of sequence correlation

The application of the generalized difference method to eliminate model autocorrelation yields the following results, which is the regression model(3).

lnGDP=1.452+0.051lnX1+0.159lnX21+0.162lnX22+0.621lnX3+1.534AR(1) -0.572AR(2) (3)

T = (2.39) (2.37) (5.41) (5.44) (10.76) (11.53) (-4.38)

R^2=0.999917, SC=-3.718325, F=61837.62, DW=2.114677, N=44.

Based on the analysis, the regression model (3) passes the F-test, indicating that the overall model is significant. Additionally, all independent variables, lnX1, lnX21, lnX22, lnX3, AR(1), and AR(2), pass the variable significance test, suggesting that they are all significant predictors of the dependent variable. The model also passes the multicollinearity test as there is no significant correlation among the independent variables. Furthermore, the model passes the serial correlation test as there is no serial correlation present. Finally, the model explains 99.9917% of the overall variation, indicating a high level of explanatory power. Therefore, the regression model (3) can be considered as the optimal model.

6. Conclusion and Policy Recommendations

6.1. Conclusion

The following conclusions can be drawn from the above optimal model（3）:

At a significance level of 5%, the explanatory variables, including the logarithm of the first industry GDP (lnX1), the logarithm of the industrial GDP (lnX21), the logarithm of the construction industry GDP (lnX22), and the logarithm of the third industry GDP (lnX3), have a significant impact on the logarithm of the dependent variable, the GDP of Shenzhen (lnGDP). On average, a 1% increase in the first industry GDP is associated with a 0.051% increase in the GDP of Shenzhen, while a 1% increase in industrial GDP, construction industry GDP, and third industry GDP is associated with a 0.159%, 0.162%, and 0.621% increase in the GDP of Shenzhen, respectively.

However, there are additional factors that affect the GDP of Shenzhen, which are not considered in the analysis. These factors result in the presence of serial correlation, indicating a relationship between the GDP values of consecutive periods. To account for this correlation, a lag of two periods, or two years, is necessary. The first year lag has a positive impact on the GDP, while the second year lag has a negative impact. This lagged effect explains the economic fluctuations observed in Shenzhen.

6.2. Policy Recommendation

Based on the conclusions drawn from the optimal model, the following policy recommendations can be made:

First，Promote diversification of industries: The analysis shows that the third industry GDP has the highest impact on the GDP of Shenzhen. Therefore, policymakers should focus on promoting the growth and development of the service sector in order to further boost the overall GDP of the city.

Second，Support industrial growth: The industrial GDP and construction industry GDP also have significant impacts on the GDP of Shenzhen. It is important for the government to provide support and incentives to stimulate growth in these sectors, such as offering tax breaks or subsidies to attract investment and encourage innovation.

Third，Enhance the first industry: While the first industry GDP has a relatively smaller impact compared to the other sectors, it still plays a role in the overall GDP growth. Policymakers should consider implementing measures to support and modernize the agricultural sector, such as providing training and technology transfer to improve productivity and efficiency.

Fourth，Address serial correlation: The presence of serial correlation indicates that there are additional factors influencing the GDP of Shenzhen that are not captured in the analysis. Policymakers should conduct further research to identify and understand these factors in order to develop targeted policies and interventions to mitigate their impact on economic fluctuations.

Fifth．Long-term planning: The lagged effect observed in the analysis suggests that economic fluctuations in Shenzhen are influenced by factors from previous years. Policymakers should take a long-term perspective when formulating policies and strategies, considering the potential lagged effects and planning for sustainable and stable economic growth.

Overall, these policy recommendations aim to promote balanced and sustainable economic growth in Shenzhen by supporting the development of different industries, addressing underlying factors influencing GDP fluctuations, and taking a long-term perspective in planning and decision-making.

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