

Research Article

Application of Internet of Things Technology to Promote High-Quality Development of Resource-Based City Industrial Transformation and Upgrading Demonstration Areas

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As a new generation of information technology, the Internet of Things technology has a very broad development prospect. It can not only cultivate strategic emerging industries, but also transform and upgrade traditional industries and promote the transformation of economic development mode. Industrial transformation and upgrading is a strategic choice for high-quality development of resource-based cities. As one of the first national demonstration areas for industrial transformation and upgrading, Loudi has made good progress in industrial transformation and upgrading in recent years, with more reasonable industrial structure, gradually emerging industrial upgrading effect, optimized internal structure of industry, and the trend of green development of the industry. At present, the industrial transformation and upgrading of Loudi is hampered by the local government, enterprises, and talents, and the technological innovation is obviously insufficient. The main bottlenecks are that low fiscal revenue and less fiscal expenditure of science and technology lead to insufficient services and guidance for industrial transformation and upgrading by local governments, low R&D investment and less scientific and technological innovation results lead to weak innovation momentum for enterprises to promote industrial transformation and upgrading, low human capital reserve and low consumption potential lead to a weak fundamental guarantee for industrial transformation and upgrading driven by human capital. The suggestions are to increase financial investment in science and technology, set up local government guidance fund, play the role of financial capital in the industrial transformation and upgrading of traction and leverage guidance, guide enterprises to increase their investment in R&D, create a favorable environment for scientific and technological innovation, and strengthen the main role of enterprises in innovation in industrial transformation and upgrading, strengthen the introduction of innovative and highly skilled personnel, take a variety of measures to reform the mechanism for training innovative personnel, and ensure the fundamental guarantee for talents in industrial transformation and upgrading.

1. Introduction

Industrial transformation and upgrading is the essential requirement for developing countries to accelerate economic development and the key to the transformation and development of resource-based cities under the new normal of economic development. The outline of the 13th five-year plan and the sustainable development plan of national resource-based cities (2013–2020) clearly put forward that the optimization and adjustment of industrial structure, the transformation of economic development mode, and the

cultivation of new drivers of resource-based regional development should be placed in a prominent position. In 2017 and 2019, the National Development and Reform Commission and other five government departments built 20 industrial transformation and upgrading demonstration zones in old industrial cities and resource-dependent cities across the country and issued a series of supporting policies. The outline of the 14th five-year plan and the implementation plan for supporting the high-quality development of industrial transformation and upgrading demonstration zones in old industrial cities and resource-based cities in the

14th five-year plan further are put forward to improve the driving mechanism of industrial transformation and upgrading led by scientific and technological innovation and institutional innovation. Thus, accelerate industrial transformation and upgrading in resource-based cities driven by scientific and technological innovation and realize the high-level and rationalization of industrial structure, which is the inevitable choice for resource-based cities to change the mode of economic growth, solve the problems of regional economic development, and promote the high-quality development of regional economy.

With the rapid development of new generation information technologies such as big data, cloud computing, and the IoTs, as well as the proposal and implementation of a series of national strategies such as Made in China 2025 and The Advanced Manufacturing Partnership of the United States and Germany's Industry 4.0, the IoTs is growing rapidly in China. In 2020, the scale of China's IoTs industry has exceeded 1.7 trillion yuan. The application of IoTs technology in intelligent agricultural production, agricultural products logistics, agricultural product safety traceability, and agricultural information platform construction can comprehensively improve the development level of modern agriculture. The application of IoTs technology to traditional industrial production, sales, storage, and other links can integrate the production and operation process and industrial chain system and comprehensively improve production efficiency. The development and application of IoTs technology in intelligent transportation, medical wisdom, wearable devices, smart home, and other scenarios represents the accelerated integration of IoTs technology and traditional industries, by raising work efficiency, improving product quality, reducing production cost and resource consumption, and promoting traditional products, equipment, process, service to digital, network, and intelligent development. It can be seen that the application of IoTs technology in industry has become an important new driving force for industrial transformation and upgrading and the intelligent transformation of industrial system.

The continuous innovation and wide application of the IoTs technology, on the one hand, accelerates the integration of its application with artificial intelligence, edge computing, big data, blockchain, and other technologies. On the other hand, it also drives the continuous expansion of the market scale of the Internet of Things, and more and more enterprises are developing towards the direction of the deep application of the IoTs. In this process, how to solve the key technical problems faced by the application of the Internet of Things and how to combine the Internet of Things with advanced manufacturing technology to form a new intelligent manufacturing system have become the focus of the application of the Internet of Things technology to promote the digitization and intelligent transformation and upgrading of enterprises. At present, China is facing the following shortcomings in the development and in-depth application of Internet of Things technology: key core technologies of hardware and software such as basic chip design, high-end sensor manufacturing, radio frequency identification technology, and intelligent information

processing are relatively weak; general technical standards of IoTs terminals and platforms are lacking; and data security guarantee and governance system of digital technology rules need to be strengthened. Accelerating the construction and formation of a new digital infrastructure system driven by technological innovation is an inevitable requirement for China to promote the high-quality development of information and communication industry and support the digital transformation of the whole society.

It was clearly put forward that the development of the open-loop application of the IoTs promotes the transformation and upgrading of traditional industries in the outline of China's 13th Five-Year Plan; it was also proposed to promote the comprehensive development of the mobile IoTs and build a new digital infrastructure system driven by technological innovation in the 14th Five-Year Plan for the development of information and communication industry. Therefore, vigorously promote the IoTs technology innovation, business innovation, model innovation, and integrated innovation, accelerate mining IoTs commercial value, and promote the penetration and integration of IoTs technology into traditional industries such as industrial manufacturing, modern agriculture, consumption, and people's livelihood, which are of great significance to promote the transformation of regional economic development mode from production-driven to innovation-driven and promote the digital transformation and upgrading of economic society.

Since the central Hunan (Zhuzhou-Xiangtan-Loudi) industrial transformation and upgrading demonstration zone was successfully approved as the first batch of national industrial transformation and upgrading demonstration zone, Loudi has accelerated the pace of industrial transformation and upgrading and implemented the strategy of building an expansion area of Changsha and integrating into Changsha-Zhuzhou-Xiangtan and made great efforts to explore effective ways of transformation and upgrading of traditional advantageous industries, development of emerging industries, industrial division and collaboration, and industrial innovation cooperation. Focusing on industrial projects, Loudi has upgraded traditional manufacturing industry, developed emerging industries and advanced structural materials industry, and concentrated on building "twin engines" of new steel materials and construction machinery and "material valley" rising in central China. However, relying on the path of resource-based cities, Loudi's industrial transformation and upgrading is confronted with key problems such as insufficient endogenous power, weak platform support, and weak characteristic industrial clusters, which seriously restrict its high-end, agglomeration, and intelligent development of industry. It is a realistic topic for Loudi to accelerate industrial transformation and upgrading and urban transformation and development under the new normal of economic development to actively explore the innovative path of industrial transformation and upgrading that adapts to local reality and highlights industrial characteristics.

This paper takes Loudi, a resource-based city demonstration zone for industrial transformation and upgrading, as an example and analyzes the innovation driving factors such

as local government, enterprises, and talents in the industrial transformation and upgrading by using the statistical bulletin data of national economic and social development of Hunan province and Loudi city from 2016 to 2021. This paper aims to explore an effective path to give full play to the decisive role of market players in resource allocation and the innovative guiding role of local governments, so as to better promote the upgrading of market players and the high-quality development of resource-based city industrial transformation and upgrading demonstration areas.

2. Status of Industrial Transformation and Upgrading Demonstration Zones in Resource-Based Cities

2.1. There Is a Sound Foundation for Industrial Transformation and Upgrading. Since the 19th CPC National Congress, Loudi has implemented the guiding principles of General Secretary Xi Jinping's important speeches, comprehensively implemented the new development concept, decisions, and plans of the CPC Central Committee and Hunan Provincial Party Committee, and vigorously implemented the strategy of "three high and four new." With building "twin engines" of advanced manufacturing industry and "material valley" in central China as the focus, the IoTs technology has been applied to key fields such as intelligent manufacturing, smart factories, and smart logistics to optimize production and business implementation procedures, integrate the operation system of industrial chain, and improve the network, information, and intelligence level of traditional industries, which has improved production efficiency while reducing the waste of production resources. Loudi has carried out beneficial exploration to promote high-quality rise in the transformation and development of resource-based city. Figure 1 shows the development of Loudi's GDP from 2016 to 2021; it shows a stable growth trend in Loudi's economic aggregate and growth rate. In 2021, Loudi's GDP reached \$182.576 billion, with a year-on-year growth of 7.7%. Affected by the epidemic, the average growth in two years was 5.8%, higher than the national average level, which provides a good foundation for the industrial transformation and development of Loudi.

2.2. The Industrial Structure Has Become More Rational and Industrial Upgrading Has Made Good Progress

2.2.1. The Structures of Primary, Secondary, and Tertiary Industries Are More Reasonable. As a typical resource-based city, Loudi has focused on the adjustment of industrial structure, developed and strengthened advanced manufacturing industries such as construction machinery and new steel materials in recent years, and achieved good results in industrial transformation and upgrading. The first industry is relatively stable, the second industry proportion decreased, and the proportion of the tertiary industry increased. The proportion of Loudi's three industries is adjusted from 11.0:41.6:47.4 in 2017 to 11.2:39.6:49.2 in 2021. In 2021, the contribution rate of the three industries to the city's economic growth is 14.2%, 30.2%, and 55.6%,

respectively, which indicates the industrial structure of Loudi is constantly optimizing, as shown in Figure 2.

2.2.2. The Upgrading Effect of Industrial Structure Gradually Appears. With the rapid development of new generation of information technology and the continuous advancement of intelligent manufacturing, relying on the IoTs technology, smart home products such as smart locks and wearable devices are increasingly being used by people; smart factories, smart transportation, and smart energy have become the fastest growing areas of industrial IoT. Many enterprises combine their own profound technological precipitation and rich application scenarios to apply the IoTs technology to the transformation and upgrading of traditional industries, and the effect is obvious. For example, relying on the Internet, IoTs, big data, and artificial intelligence, Lengshuijiang vigorously developed and utilized smart steel manufacturing technology and equipment. With the help of Internet and IoTs technology, all complex processes are controlled by a microcomputer; the new energy power battery developed and produced by Hunan 3SUN New Energy Technology Company has successfully entered the markets of Germany, the United States, Australia, and other countries and is widely used in rail transit, communication base stations, ships and submarines, and other fields. The integration of IoTs technology and traditional industries drives the transformation of industrial chain from manufacturing to service and the transformation of industrial structure from traditional manufacturing to service solutions. The servitization of economic structure has become an important feature of industrial structure upgrading. Referring to the practice of Wang et al. [1], the paper adopts the ratio of output value of tertiary industry and secondary industry to measure the advanced level of industrial structure, which is expressed by formula

$$is = \frac{y_3}{y_2}, \quad (1)$$

where y_2, y_3 represent the added value of secondary industry and tertiary industry, respectively, is represents the advanced index of industrial structure, and the larger the value, the higher the economic level and the better the industrial structure. From Figure 3, we know that, during 2016 ~ 2021, Loudi vigorously promoted the traditional industry upgrade and sped up the development of strategic emerging industries; to strengthen the industrial advantage of emerging industry chain, good progress was made in industrial upgrading. The proportion of the secondary industry continues to decline, while that of the tertiary industry continues to rise and has gradually grown into the leading industry in Loudi, and the upgrading of the industrial structure is steadily advancing.

2.3. Large-Scale Industries Grew Rapidly and the Industry Structure Was Optimized

2.3.1. The Proportion of Value-Added of Large-Scale Industry Increases. Loudi vigorously promotes the supply-side structural reform, changes the mode and adjusts the

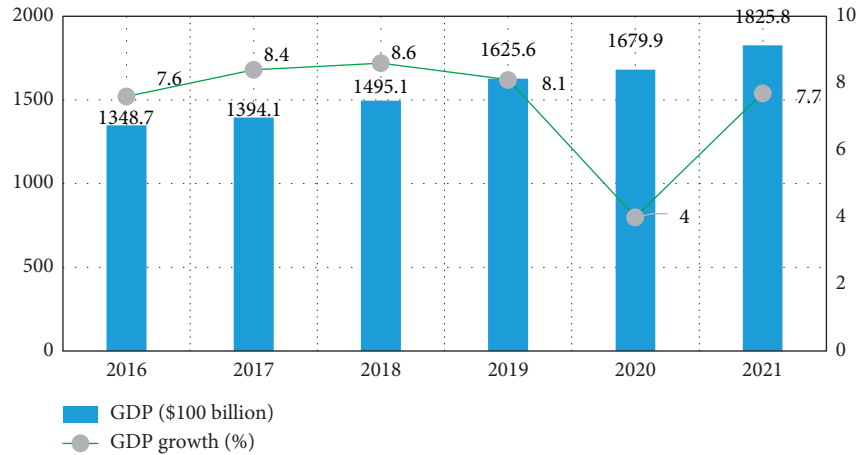


FIGURE 1: The development of Loudi's GDP and its growth rate from 2016 to 2021.

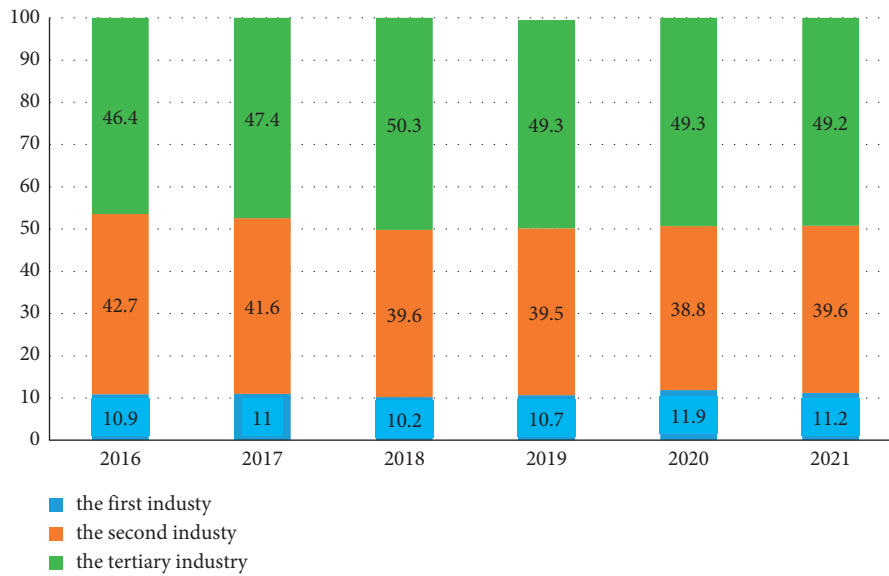


FIGURE 2: Changes in the proportion of Loudi's three industries from 2016 to 2021.

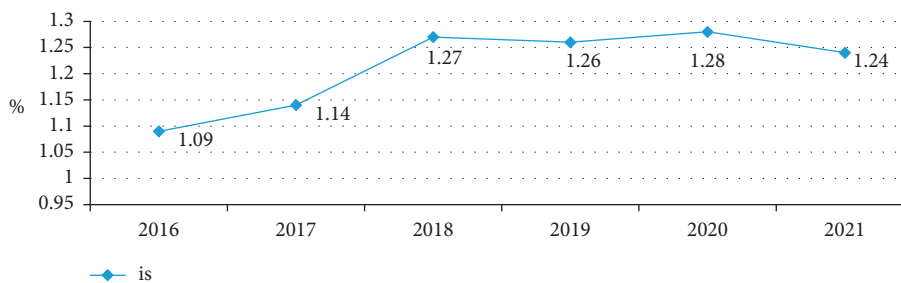


FIGURE 3: Advanced industrial structure of Loudi city from 2016 to 2021.

structure, and has achieved obvious results through “three eliminations, one reduction, one supplement.” The industrial structure has been continuously optimized, and large-scale industries have grown rapidly. Figure 4 shows the growth of value-added of large industrial enterprises in

Loudi from 2016 to 2021. The value-added of large industrial enterprises in Loudi has maintained a sustained and rapid growth, with an average annual growth rate of 7.3%. In 2020, due to the impact of COVID-19, the growth rate dropped to 5.7%, which is also higher than the industrial value-added

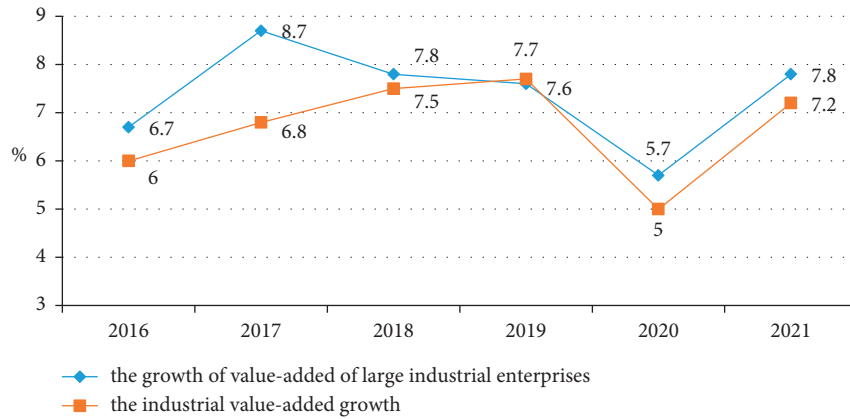


FIGURE 4: Growth rate of large-scale industrial added value in Loudi from 2016 to 2021.

growth in the same period, indicating that the industrial internal structure of Loudi has been improved and the proportion of large-scale industries has been rising.

2.3.2. The Structure of Large-Scale Industries Has Been Optimized. Table 1 reflects the growth and change of the industrial structure of large-scale industries in Loudi from 2016 to 2021. It can be seen that technology-intensive industries such as pharmaceutical manufacturing, special equipment manufacturing, and general equipment manufacturing develop well, and the added value of large-scale industries keeps a good growth rate. On the other hand, coal mining, chemical raw materials and chemicals, non-ferrous metal smelting, and other industries with high pollution and high energy consumption have achieved significant reduction in capacity, and the added value of large-scale industries has continued to decline.

2.4. High-Tech Industries Are Developing Rapidly and the Trend of Green Industrial Development Continues to Strengthen

2.4.1. The Proportion of High-Tech Industries Is on the Rise. Loudi has successively issued implementation plans to accelerate the development of industrial chain with Table 1.

Data source: Industrial economic indicators from January to December of Loudi Municipal Bureau of Statistics emerging advantages promote the construction of industrial projects, focusing on building 10 industrial chains with emerging advantages, which are high-quality steel and sheet steel deep processing, engineering machinery and auto accessories Internet and big data, advanced ceramic materials, advanced energy storage materials, food processing and biomedical, modern agricultural machinery equipment, prefabricated construction, modern printing, energy conservation, and environmental protection. Loudi has actively cultivated four industrial clusters including new materials, intelligent manufacturing equipment, biomedicine, and modern service industry. It has attracted a large number of high-tech enterprises represented by Boltpower, 3Sun

Electronics, and Shanghai XKCHEM to gather in Loudi, and the added value of high-tech industry and its proportion in GDP keep rising. Figure 5 reflects the change of added value and proportion of high-tech industry in Loudi city from 2016 to 2021. In 2021, the added value of high-tech industry in Loudi reached \$40.06 billion with an increase of 23.6% compared with last year, and the proportion of added value of high-tech industry in GDP increased to 21.9%. There are 2,897 patents granted with 12.7 percent more than last year, including 215 invention patents, 56.9 percent more than last year. Focusing on scientific and technological innovation, Loudi is full of vitality in enhancing core competitiveness and developing new drivers. Loudi Advanced Structural materials industrial cluster is listed as the national first batch of strategic emerging industrial cluster development project, and Loudi high-tech zone was selected as the site inspection list of Ministry of Science and Technology in 2021.

2.4.2. The Trend of Green Industrial Development under the Constraint of Ecological Environment Continues to Strengthen. Loudi adheres to intensive conservation and recycling in its transformation and upgrading, promotes energy conservation, emission reduction, and consumption reduction, constantly explores a green development model under strict ecological environment constraints, persists in taking the elimination of backward production capacity as an important measure of transformation and upgrading, and focuses on cleaning and reorganizing enterprises with high energy consumption and high emissions. Enterprises with high energy consumption that do not conform to the national industrial policy and have no environmental protection facilities have been ordered to stop production or dismantle their equipment. Meanwhile, Loudi vigorously develops green manufacturing and ecological environmental protection industry, strengthens the coordinated control of atmospheric pollutants, and as a whole pays special attention to the water source protection and urban black smelly water governance, guiding the soil pollution control and repair, with implementation to green ecological transformation of industrial development, with a high level of environmental

TABLE 1: The growth of value-added of large industrial enterprises unit: %.

| Year | Mining and washing of coal | Food from agricultural product | Petroleum, coal, and other fuel | Chemical raw materials and products | Medical industry | Nonmetal mineral products | Nonferrous metals | Ferrous metals | Special equipment | General machinery | Electricity and heat | Water |
|------|----------------------------|--------------------------------|---------------------------------|-------------------------------------|------------------|---------------------------|-------------------|----------------|-------------------|-------------------|----------------------|-------|
| 2016 | 0.9 | 13 | -3.8 | 1.3 | 8.5 | 5.7 | -11.3 | 6.4 | 10.2 | 10.1 | -0.1 | -9.5 |
| 2017 | 19.1 | 30.6 | -22.6 | -8 | 18.7 | 0 | -21.4 | 10.7 | 18.8 | -0.1 | 2.4 | 2.4 |
| 2018 | -18.2 | 8.4 | 8.7 | 1.8 | 20 | 11.1 | 0 | 6.7 | 2.9 | 25.7 | 11 | 6.1 |
| 2019 | -7.5 | -1.6 | 6.7 | -7.6 | 25.8 | 4.5 | 35 | 1.1 | -6.8 | 22.8 | 3.4 | -17.2 |
| 2020 | -10.8 | -1.2 | 7.3 | -8.1 | 10.9 | 5.9 | 2.5 | 8.7 | 24.4 | -5.1 | -1.3 | 3.9 |
| 2021 | -35.4 | -2.2 | -10.6 | -25.2 | 20.8 | -6.4 | -29.8 | -6.1 | -1.7 | 1.6 | 11.1 | 2.8 |

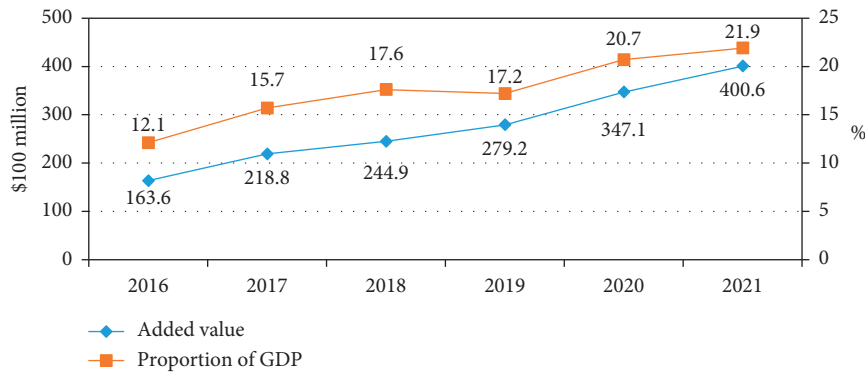


FIGURE 5: Added value of high-tech industry and its proportion in GDP of Loudi from 2016 to 2021.

protection to promote realizing the entire development of high quality. The index of energy consumption reduction rate per \$10,000 of GDP in Loudi 2016~2020 (Table 2) shows that the energy consumption per \$10,000 of GDP in Loudi has decreased significantly, and the growth rate of total energy consumption tends to decline. The target task of energy conservation and consumption reduction issued by Hunan province has been successfully completed. In 2020, the energy consumption per \$10,000 of GDP has decreased by 2.52% and the power consumption has decreased by 0.32%.

3. The Main Constraints of Industrial Transformation and Upgrading in Resource-Based Cities

The industry transformation and upgrading of resource-based cities is inseparable from scientific and technological innovation and institutional innovation [2], innovation-driven is the core to relieve low-end production capacity, develop emerging and alternative industries, and promote the transformation and extension of industrial chain to high-tech and high value-added industries [3], and capital and talents are important driving factors of innovation ecosystem in resource-based cities [4]. The industrial transformation and upgrading of Loudi is restricted by many factors, such as local government financial restriction, insufficient innovation main role of enterprises, lack of innovation talents, and so on, and innovation drive is obviously insufficient.

3.1. Insufficient Local Government Services and Guidance for Industrial Transformation and Upgrading

3.1.1. The Local Fiscal Revenue Is Low and the Fiscal Drive for Industrial Transformation and Upgrading Is Insufficient. Resource-based cities used to be important national resources and energy bases. In the period of transformation and development, resource-based cities face the dual challenges of ensuring resource supply for national economic development and sustainable development of cities themselves. Industrial transformation and upgrading of resource-based cities cannot be achieved without policy guidance and

financial support from local governments. On the basis of respecting the decisive role of the market in resource allocation, it is necessary to give full play to the role of local governments in overall coordination, planning guidance, fiscal and tax support, institutional innovation, and public service [5]. Among them, industrial policy is an important starting point for the government to promote industrial development and industrial structure transformation and upgrading. By formulating a series of industrial policies, local governments can change the structure of regional factor endowment, guide technological innovation of enterprises, and promote industrial transformation and upgrading and cluster development. The local government's industrial policy inevitably involves financial support, and the degree of financial dependence is an important index to measure the quality of local economic development and local industrial structure. Generally speaking, the degree of fiscal dependence is relatively high in areas with high quality of economic operation, low proportion of primary industry, significant proportion of emerging industry, resource-based industry, and high value-added industry. Table 3 reflects the changes of local fiscal revenue growth in Loudi city and Hunan province from 2016 to 2021. It is obvious that the total local fiscal revenue of Loudi keeps increasing, and its growth rate is basically higher than that of the whole province in the same period. However, the proportion of local fiscal revenue in GDP continues to be low, between 4.5 and 5.0, which has a large gap with Hunan province. This shows that, on the one hand, Loudi's economic quality is not high, the level of industrial structure is low, and there are few industries with high added value and high profit margin and refined and deep processed products; on the other hand, the local government of Loudi has limited financial resources and lacks the ability to promote the transformation and upgrading of industrial structure by mobilizing resources.

3.1.2. Government Expenditure on Science and Technology Is Low and Scientific and Technological Innovation Support for Industrial Transformation and Upgrading Is Weak. Local fiscal science and technology expenditure plays a good support in technological innovation and is the main direct driving force for the long-term development of local economy [6]. The transformation and upgrading of

TABLE 2: Energy consumption reduction rate per \$10,000 of GDP in Loudi 2016~2020.

| Year | Energy consumption per \$10,000 of GDP rises or falls ($\pm\%$) | Growth in total energy consumption (%) | Electricity consumption per ten thousand of GDP rises or falls ($\pm\%$) |
|------|---|--|--|
| 2020 | -2.52 | 1.41 | -0.32 |
| 2019 | -5.29 | 2.41 | -5.74 |
| 2018 | -5.92 | 2.17 | 1.06 |
| 2017 | -5.87 | 2.12 | -3.64 |
| 2016 | -5.44 | 1.79 | -5.55 |

Source: Index Communiqué of energy consumption reduction rate per \$10,000 of GDP of cities from Hunan Provincial Bureau of Statistics during 2016~2020.

TABLE 3: Total fiscal revenue, growth rate, and proportion in GDP of Loudi city and Hunan province from 2016 to 2021.

| Year | Local fiscal revenue of Loudi | | | Local general public budget revenue of Hunan province | | |
|------|-------------------------------|------------|-----------------------|---|------------|-----------------------|
| | Total amount (\$100 million) | Growth (%) | Proportion of GDP (%) | Total amount (\$100 million) | Growth (%) | Proportion of GDP (%) |
| 2016 | 68.25 | 13.9 | 4.87 | 2697.88 | 7.3 | 8.63 |
| 2017 | 70.29 | 5.2 | 4.55 | 2757.82 | 4.9 | 7.97 |
| 2018 | 70.30 | 0.02 | 4.56 | 2860.84 | 3.73 | 7.85 |
| 2019 | 76.70 | 9.1 | 4.68 | 3006.99 | 5.11 | 7.56 |
| 2020 | 80.61 | 5.1 | 4.80 | 3008.70 | 0.1 | 7.20 |
| 2021 | 90.77 | 12.6 | 4.97 | 3250.70 | 8.0 | 7.06 |

industrial structure need the guidance and support of science and technology input from local government. Fiscal expenditure on science and technology is an important means to stimulate innovation. The increase of fiscal expenditure on science and technology of local governments can promote the number of patent applications granted and the turnover of technology market, thus promoting the improvement of regional innovation ability [7]. At the same time, fiscal science and technology expenditure has a strong promotion effect on improving innovation infrastructure, building innovation platform, and R&D investment subsidy, which can guide investment agglomeration and improve regional innovation level [8]. In particular, financial expenditure on science and technology will help promote the research and development of IoTs technology, the promotion and application of IoTs technology demonstration, key generic IoTs technology, and basic public platform construction, which will foster the development of IoTs industry and promote the transformation and upgrading of regional economy. Figure 6 shows the growth of fiscal science and technology expenditure in Loudi from 2016 to 2021. Loudi actively implements the innovation-driven development strategy, vigorously supports scientific and technological innovation, and takes science and technology as a key area of financial expenditure. Since 2017, the local financial expenditure on science and technology in Loudi has maintained an annual growth rate of more than 37%, and the growth rate reached 114.6% in 2018. The proportion of the municipal public finance budget expenditure also keeps an obvious growth trend, increasing from 0.27% in 2016 to 1.58% in 2020. But compared with Hunan province, the proportion of financial expenditure on science and technology in Loudi is far lower than that in Hunan province, which shows that Loudi's financial input to support scientific

and technological innovation is too low, and the impetus of financial expenditure to guide and support scientific and technological innovation is insufficient. As a result, the construction of scientific and technological innovation infrastructure and innovation platform in Loudi lags behind, which is not conducive to the R&D of new products and technological upgrading and restricts the development of regional industrial transformation and upgrading.

3.2. Enterprises Have Weak Innovation Driving Force to Promote Industrial Transformation and Upgrading. Scientific and technological innovation is the internal driving force of industrial transformation and upgrading. Loudi issued the opinions of implementing the innovation-leading strategy to build a strong city with science and technology in 2017 and increased policy support from the aspects of improving innovation ability, constructing regional innovation public service system, strengthening the leading position of enterprises in innovation, cultivating and gathering scientific and technological innovation talents, and so on. Since the 13th five-year plan, Loudi's R&D expenditure, R&D intensity, number of R&D personnel, and number of research institutions have shown a trend of steady growth. However, there are still low R&D investment intensity, insufficient physical capital and human capital investment, and a low number of R&D institutions in Loudi, and the innovation-driven industrial transformation and upgrading need to be further improved.

3.2.1. Enterprise R&D Investment Is Low and the Main Role of Enterprise Innovation Is Not Fully Reflected. R&D investment intensity is an important index to measure a region's innovation ability and comprehensive

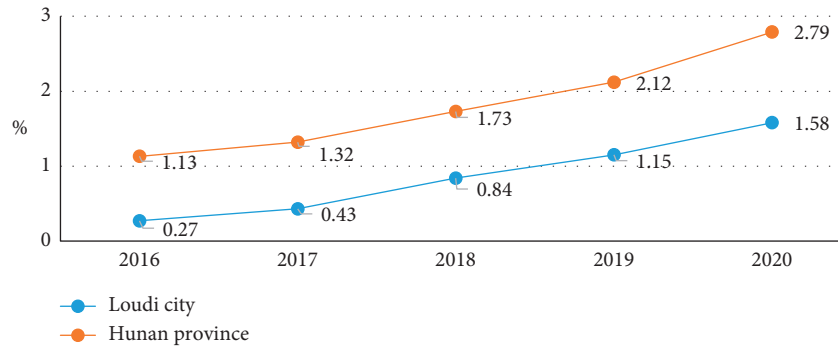


FIGURE 6: Proportion of science and technology expenditure of local finance in public finance budget expenditure of Loudi city and Hunan province during 2016~2020.

competitiveness. In recent years, the R&D expenditure in Loudi has shown a rapid growth trend. According to the statistics of Hunan Provincial Statistical Yearbook, the R&D expenditure in Loudi was only \$1.277 billion in 2016 and it increased to \$3.015 billion in 2020. However, from the perspective of R&D investment intensity, the R&D investment intensity of Loudi enterprises has been at a low level for a long time. In 2020, the R&D investment intensity of Loudi is only 1.79%, while Hunan's R&D investment intensity is 2.15% in the same period. Low R&D investment seriously affects the sustainable development of Loudi economy. R&D personnel are the main force of enterprises' scientific and technological activities, and it determines the quality of enterprises' innovation activities. In recent years, Loudi has increased the introduction and investment of scientific and technological talents. Through targeted introduction, flexible introduction, and expert recommendation, the R&D personnel team of the city has been continuously expanded. In 2020, there were 8,300 R&D personnel in Loudi's scale industrial enterprises, an increase of 29.0% compared with the same period last year. However, in general, Loudi enterprises have insufficient investment in R&D personnel. More than 80% of R&D personnel concentrated in high-tech enterprises, and small and micro high-tech enterprises have few R&D personnel, which has not fundamentally solved the problem of lack of R&D and innovation talents in Loudi. It is still common for enterprises to fail to attract and retain high-end technical talents that are in short supply. The low investment of R&D personnel leads to the lack of independent innovation in the city, and it is difficult to effectively improve the industrial innovation ability.

3.2.2. There Are Few Main Bodies of R&D Innovation, and the Construction of Enterprise Innovation Platform Lags Behind. According to the statistics yearbook of Hunan province, in 2020, there are 464 industrial enterprises above designated size and 52 large and medium-sized industrial enterprises with R&D activities in Loudi, an increase of 27% compared with the same period of last year. However, in general, the proportion of enterprises with R&D activities in Loudi is low, and there are few subjects of R&D innovation. Most of the enterprises' products are based on traditional industries. Some large and medium-sized enterprises have

neither R&D activities nor R&D projects to report in their annual reports, so their R&D innovation motivation is very weak. Most traditional industrial enterprises lack independent R&D institutions and teams, and their independent innovation ability is low. The number of scientific research institutes in Loudi is small, the stable cooperation between enterprises, scientific research institutes, and universities has not been fully established, and the industry-university-research cooperation service platform has not played its due role.

3.2.3. Few Scientific and Technological Innovation Achievements and Insufficient Innovation Momentum. Although the number of patent applications and patent authorization in Loudi has shown a trend of steady growth in recent years, compared with the whole province (see Table 4), the number and the growth of patent applications and patent authorization in Loudi are small, accounting for a relatively low proportion. By 2020, the number of patent applications in Loudi was 5,588, only accounting for 4.07% of the number of patent applications in Hunan province, and the number of authorized patents was 2,571, only accounting for 4.67% of the number of authorized patents in Hunan province, which made difficult it to effectively improve the city's industrial independent innovation ability.

3.3. The Fundamental Guarantee for Industrial Transformation and Upgrading Driven by Human Capital Is Insufficient. Population is one of the important factors affecting the transformation and upgrading of industrial structure. Many studies analyze the mechanism of economic growth and industrial structure optimization from the perspective of human capital and believe that the improvement of human capital can promote economic growth, optimize the industrial structure [9,10], and promote the development of the industry to the direction of advancement [11]. From the perspective of demographic structure, some studies put forward that a lower total dependency ratio is conducive to labor transfer, which means that population provides better conditions for economic growth and is more conducive to the transformation and upgrading of industrial structure [12].

TABLE 4: The proportions of Loudi's patent application and authorization in the whole province from 2016 to 2021.

| Year | Proportion of patent applications (%) | Proportion of licensed patents (%) |
|------|---------------------------------------|------------------------------------|
| 2020 | 4.07 | 4.67 |
| 2019 | 2.93 | 3.26 |
| 2018 | 2.89 | 3.43 |
| 2017 | 2.40 | 3.01 |
| 2016 | 2.33 | 3.21 |
| 2015 | 2.97 | 2.94 |

3.3.1. With a Lower Level of Industrial Structure and a Higher Dependency Ratio, Loudi Has a Heavy Burden on Industrial Transformation and Upgrading. As a young prefecture-level city, Loudi still has a big gap between its industrial structure and that of the whole country. In 2021, the proportion of added value of the three industries in Loudi is 11.2:39.6:49.2, while that of the whole country is 7.3:39.4:53.3. Comparatively speaking, Loudi has a high proportion of primary industry, a heavy proportion of secondary industry, and insufficient development of tertiary industry. There is a long way to go for the transformation and upgrading of Loudi's industrial structure. At the same time, Loudi's population structure cannot provide a good driving support for its industrial structure transformation and upgrading. According to the seventh population census, the proportion of population aged 15~59 in Loudi is only 58.18%, that of Hunan province is 60.60%, and that of the whole country is 63.35%. The proportion of working-age population in Loudi is 2.42 percentage points lower than that of the whole province and 5.17 percentage points lower than that of the whole country (see Figure 7). This means that the lower level of industrial structure of Loudi is accompanied by a higher dependency ratio of population, and the phenomenon of "getting old before getting rich" and labor shortage is more obvious in Loudi, a resource-based city.

3.3.2. With Low Human Capital Reserve, Loudi Lacks the Talent-Driven Power for Industrial Transformation and Upgrading. From the perspective of population quality, the seventh census data shows that there are 15,467 people with university education (junior college or above) per 100,000 people in China and only 12,239 people in Hunan province, less than 80% of the national average. There are 30,555 students with high school (including technical secondary school) or above in China, while there are only 30,015 students in Hunan province, slightly lower than the national average. The average length of education of the population aged 15 and above is 9.91 years in China, only 9.88 years in Hunan province, and 9.70 years in Loudi city, also lower than the national average. This means that when China's demographic dividend disappears and the comparative advantages of traditional industries weaken, we need to improve the level of human capital to drive the improvement of labor productivity and industrial transformation and upgrading and boost high-quality economic development. General Secretary Xi Jinping has repeatedly stressed the need

to increase investment in human capital. The report to the 19th CPC National Congress called for accelerating the building of an innovative country, stressing that talent is a strategic resource for achieving national rejuvenation and winning the initiative in international competition. In human capital cultivation, Hunan province, especially Loudi, has a long way to go.

3.3.3. The Uncoordinated Population Structure Also Restricts the Expansion of Market Consumption Potential and Hinders Industrial Transformation and Upgrading. As we all know, per capita disposable income is positively correlated with consumer expenditure. The more developed a country is, the higher per capita disposable income is, and the higher its consumer expenditure level is. The market consumption potential of an area is influenced by the disposable income of its residents. According to the per capita disposable income and per capita consumption expenditure of Loudi (see Figure 8), the per capita disposable income of Loudi residents is \$24,010 in 2021, and the per capita consumption expenditure is \$18,328, while the per capita consumption expenditure of Hunan province is \$31,993 and \$22,798, respectively. The per capita disposable income and consumption expenditure of Loudi residents are less than 3/4 of the average level of Hunan province. Low income is accompanied by low consumption potential, which also means that Loudi city faces greater pressure to promote industrial structure adjustment and upgrading through consumption upgrading.

4. Countermeasures for the Construction of Demonstration Areas for Industrial Transformation and Upgrading in Resource-Based Cities

4.1. Innovate the Means and Methods of Local Government Services and Guide Industrial Transformation and Upgrading

4.1.1. Increase Financial Investment in Science and Technology and Give Full Play to the Leading Role of Financial Expenditure in Scientific and Technological Innovation. Fiscal expenditure on science and technology can effectively improve the level of urban innovation by promoting the output of enterprises' invention patents and guiding urban investment agglomeration [9]. The outline of the 14th five-year plan calls for increasing financial input in basic research and promoting the optimization and upgrading of the industrial structure. Loudi fiscal expenditure on science and technology foundation is weak; the innovation platform construction of infrastructure such as poor foundation, under the condition of the reasonable expenditure intensity, urgently needs to change ideas, supports scientific and technological innovation in the important position of public finance, optimizes the structure of fiscal expenditure, general spending, and compression, continues to increase financial investment in science and technology to greatly raise the proportion of fiscal expenditure of science and technology

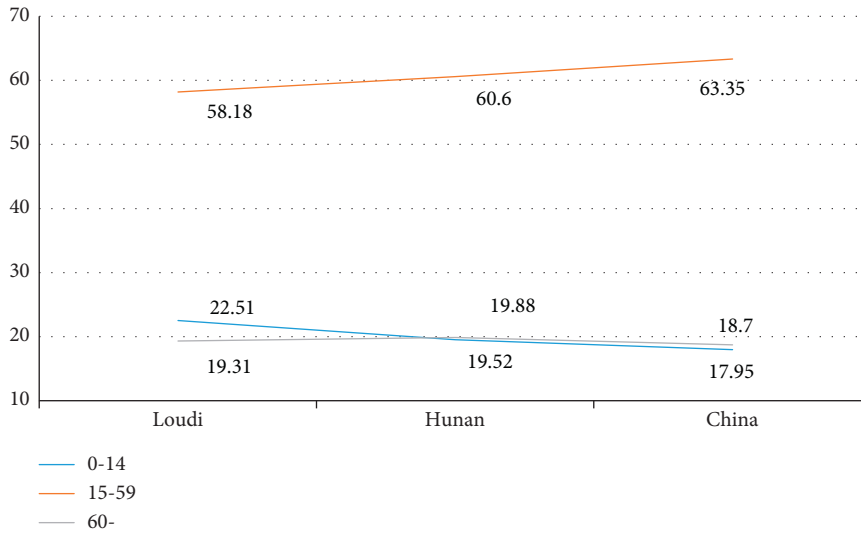


FIGURE 7: Population age composition of Loudi city, Hunan province, and China in the seventh population census.

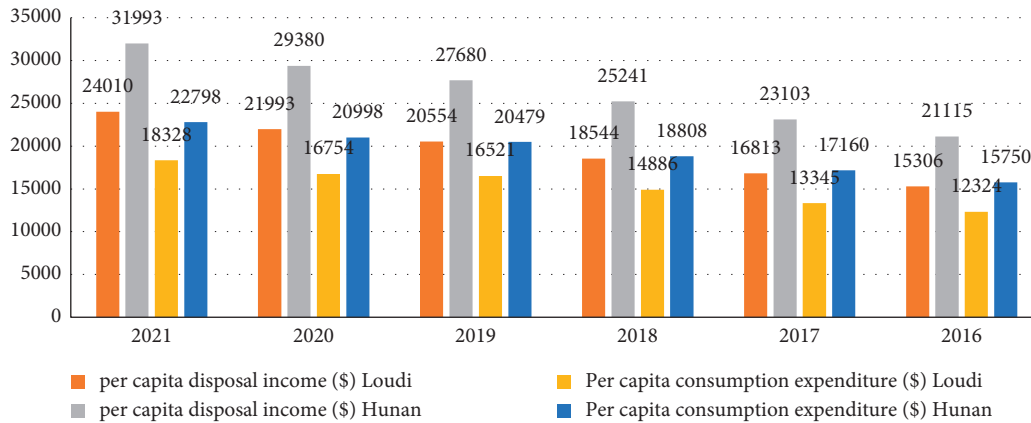


FIGURE 8: Growth of per capita disposable income and per capita consumption expenditure of Loudi city and Hunan province from 2016 to 2021.

and innovation incentives of financial support for scientific and technological innovation, strengthens the effect of fiscal expenditure of science and technology of dynamic regulation, focusing on establishing a new development pattern of Loudi in key areas and strategic emerging industries, better plays with the effect of fiscal expenditure of science and technology innovation, and guides and motivates fiscal expenditure on science and technology enterprise technological innovation, to drive the industry to the direction of high-end, greening, intelligence, integration, and development.

4.1.2. Set Up Local Government Guidance Fund to Drive Industrial Transformation and Upgrading. In recent years, local government guide fund, as an emerging mode of industry and finance integration and equity investment, has been highly praised by many local, provincial, and local governments and has rapidly developed into an important support force for optimizing local industrial structure,

promoting industrial transformation and upgrading, and promoting industrial innovation and reform. Data from Zero2IPO Research Center shows that China had set up a total of 1,988 government guide funds by the end of 2021, with a target scale of about \$12.45 trillion and a subscribed size of about \$6.16 trillion. This year, Changsha high-tech zone initiated the establishment of 20 billion yuan’s angel mother fund and seed fund, focusing on the park “113” modern industrial system (the first “1” represents the new generation of information technology as the first industry, the second “1” represents construction machinery as the dominant industry, and the “3” represents biomedicine, advanced energy storage and new energy vehicles, and aerospace as the featured industry). Practice shows that the local government guiding fund through the guidance of financial capital leverage effect, promoting investment institutions and social capital to participate in, revitalizes the stock resources, to guide our orientation in foreign capital scale and to attract financial capital and social capital into the local leading industries, strategic emerging industry

enterprises, and science and technology innovation-oriented enterprises, promote technological innovation and technology industrialization, stimulate the endogenous power of economic transformation, and promote the transformation of traditional industries to intelligent manufacturing, so as to optimize the industrial structure and realize the macro-control function of local government on industrial transformation and upgrading. Loudi government can draw lessons from the successful experience of the local governments to guide fund operation, choose the right industry, select the qualified investment institutions, establish a science fund investment operation management supervision and exit mechanism, correct the good markets playing a decisive role and guiding role of the government, and realize nesting on a promoting industrial transformation and upgrading of the target for a long time.

4.2. Give Full Play to the Major Role of Enterprises in Innovation and Consolidate the Micro Foundation for Industrial Transformation and Upgrading

4.2.1. *Guide Enterprises to Increase R&D Investment and Upgrade the Industrial Chain Level with Scientific and Technological Innovation.* The report to the 19th National Congress of CPC calls for accelerating the building of an innovative country and points out that innovation is the primary driving force for development. China's economy is now at a critical stage of replacing old drivers of growth with new ones. To achieve high-quality economic development, we need to further leverage the innovation-driven transformation and upgrading of the industrial structure as an important driving force. Studies showed that the amount of innovation in China has a significant role in promoting the transformation and upgrading of industrial structure [13]. Technological innovation driving the optimization and upgrading of industrial structure is an objective requirement for China's sustained economic development and the optimal choice for transforming the economic development mode. To promote the integration of informatization, intelligence and industrialization with the new generation of information technology such as IoTs is an important focus of advanced manufacturing driven by technological innovation at present. Characterized by innovation, high permeability, and positive externalities, the IoTs enables enterprises to achieve real-time data information, real-time inventory monitoring and management, efficient production processes, and greater customer engagement and reduce the negative impact of human factors on production. The application of IoTs technology will comprehensively improve the cohesion efficiency between different economic activities and the overall efficiency of economic operation. Loudi as resource-based city, faced with the fact that the cost of various elements and resources has risen in recent years, should give full play to the main role of enterprises in scientific and technological innovation, focus on the optimization and upgrading of the industrial structure, take the IoTs technology application as the breakthrough point, combine technology introduction with independent

innovation, and increase spending on R&D of key and core technologies. We should strive to increase the economical and intensive use of energy and resources and reduce resource consumption and ecological damage and stimulate the development vitality of enterprises with technological innovation and promote the overall efficiency of the industry and the quality and upgrading of the industrial chain.

4.2.2. *Create a Good Environment for Scientific and Technological Innovation and Stimulate the Innovation Vitality of Enterprises.* Scientific and technological innovation is characterized by high input, high risk, long cycle, high uncertainty, and positive externalities, which make innovation activities inseparable from government policy support and institutional norms. The fifth plenary session of the 18th CPC Central Committee pointed out that the government should transform its functions from R&D management to innovative service. The government should serve all types of innovation subjects well, create a good institutional environment for enterprises' technological innovation, truly realize the "dual wheel drive" of technological innovation and institutional innovation, and release the innovation vitality of all types of subjects to the maximum. On the one hand, Loudi should vigorously publicize and effectively implement the relevant national R&D incentives and tax incentives, improve the government R&D subsidies, strengthen the protection of scientific and technological innovation achievements, reduce the institutional cost of enterprises' innovation R&D activities, and enhance enterprises' innovation R&D ability to effectively drive the transformation and upgrading of industrial structure. On the other hand, Loudi needs to improve the R&D financial services and investment and financing system, solve the financing problems of high-tech enterprises, and enhance the endogenous impetus for enterprises to innovate.

4.3. Implement the Strategy of Innovation-Driven Talents to Lay a Solid Foundation for Industrial Transformation and Upgrading

4.3.1. *Strengthen the Introduction of Innovative and High-Skilled Talents.* Talent is the first resource to support innovative development, high-quality talent is the core resource to promote economic development, and innovative talent is the key factor for industrial transformation and upgrading. Loudi should vigorously implement the action plan for innovative talents in the new era, take the development of emerging industries as the breakthrough point, focus on the introduction of high-level innovative scientific and technological talents and talents in short supply, and attract various innovative talents widely. The government should play the role innovation talent introduction guide, investigate the needs of various types of innovative talents for industrial transformation and upgrading, and promote institutional reform and policy innovation for talent development. More competitive measures will be adopted to attract qualified new talents, and preferential policies will be provided to qualified new talents in such areas as

recruitment, housing, spouse placement, children's education, medical care, comprehensive subsidies, and individual income tax rewards. Loudi should strengthen the building of talent recruitment work platform and establish talent supply and demand information database. For high-level and scarce talents urgently needed for the industrial transformation and upgrading, Loudi governments can attract talents through overseas talent workstations and domestic third-party professional talent service agencies and attract all kinds of talents to innovation and entrepreneurship through talent exchange, talent fair, project scientific research achievement promotion, project matchmaking, and other platforms.

4.3.2. Innovate Talent Training Methods and Reform Innovative Talent Training Mechanism through Multiple Measures. Industrial transformation and upgrading are inseparable from the transformation of talents. Developed cities and coastal open cities obviously have more advantages in terms of high-level talent introduction. Loudi is an inland province city, faced with fierce competition and serious introverted talent in big cities. Loudi should focus more on talent cultivation and promotion and innovate talent cultivation methods. On the one hand, to meet the demand of skilled talents for industrial transformation and upgrading, Loudi should strengthen vocational skills training, build vocational skills training system, and encourage multisubjects to participate in vocational skills training. On the other hand, it is more important to strengthen university-local university-enterprise cooperation and cultivate and retain college graduates by deepening the integration of university-city, industry, and education. Hunan University of Humanities, Science and Technology, as the only undergraduate university in Loudi, proposed the "Action Plan for The Integrated Development of Loudi City and Construction of an Integrated City of Industry and Education" in 2021. Loudi governments and enterprises should take this opportunity to strengthen personnel training cooperation with local universities and vocational colleges, relying on the local colleges and universities and local vocational colleges and universities to meet the need of industry transformation and upgrading of high-quality talent. In particular, a large number of compound professionals are needed to serve Loudi to build "twin engines" for advanced manufacturing and "material valley" in central China and promote the deep integration of emerging technologies such as big data and artificial intelligence with manufacturing. Strengthening School-Business Partnerships can not only improve the industrial applicability of talents, but also lay a foundation for talents to stay in local areas after graduation. College graduates are the most dynamic and creative group. College graduates staying in Loudi can not only retain high-quality young people, but also attract highly educated talents from other places. On the one hand, it can get rid of the dilemma of shortage of innovative talents, and on the other hand, it can solve the impact of Loudi's aging population on industrial transformation and upgrading. At the same time, high-quality young people are also the group with the largest consumption potential in the market.

Retaining young people can also promote the transformation and upgrading of industrial structure through the expansion of the consumer market.

5. Conclusion and Further Discussion

As an important and special city group in the process of national economic development, resourcing dependence over the years makes resource-based cities face the dual shortage of power and capability in the process of industrial transformation and upgrading. The construction of industrial transformation and upgrading demonstration zone has brought a period of strategic opportunity for the industrial transformation and upgrading of resource-based cities, and the rapid development and application of the new generation of information technology represented by the IoTs has given new momentum to the industrial transformation and upgrading of resource-based cities. To accelerate the integration and penetration of IoTs technology with traditional industries, it is urgent to give full play to the dual engine driving role of local government and market entities and build a new digital infrastructure system driven by technological innovation. Specifically, for the industrial transformation and upgrading of resource-based cities, it is necessary to fully mobilize the main innovation momentum of enterprises, promote the upgrading of market entities, guide enterprises to increase R&D investment, and give full play to the decisive role of market players in resource allocation. It is also necessary to give better play to the innovation-leading role of local government, create an enabling environment for scientific and technological innovation, increase government investment in science and technology, and promote the construction of efficient government and efficient market. At the same time, it is necessary to give full play to the core supporting role of innovative talents, strengthen the introduction of innovative and highly skilled personnel, and develop new ways of training talents, to promote the virtuous cycle of innovation ecology of talents, funds, and policies and promote the high-quality development of resource-based cities.

Of course, the industrial transformation and upgrading of resource-based cities is a huge systematic project, involving industrial structure adjustment, industrial cluster construction, urban renewal and transformation, and green and low-carbon. To build innovative, green, open, coordinated, and shared industrial transformation and upgrading demonstration zone can better play the role of national industrial transformation and upgrading demonstration zone as the core carrier of promoting regional coordinated development and new-type urbanization construction and maintaining the security of regional industrial chain and supply chain. This paper only analyzed the industrial transformation and upgrading of resource-based cities from the key roles of scientific and technological innovation: local government, enterprises, and talents. It is an issue to be further studied to know how to perfect the system and mechanism of scientific and technological innovation and comprehensively shape the new advantages of innovation-driven high-quality development of resource-based cities. At

the same time, the industrial transformation and upgrading of resource-based cities also depends on a good scientific and technological innovation ecological environment, which requires the coordinated development of a good enterprise innovation ecological system, industrial innovation ecological system, talent innovation ecological system, and innovation ecological environment system. Therefore, there are other issues to be further studied in the transformation and upgrading of resource-based cities such as how to optimize the innovation institutional environment, strengthen the combination of innovation subjects, accelerate the accumulation of innovation resources, promote the flow of innovation resources between the environment and the subjects, and build an efficient innovation ecosystem.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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