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Transformation of Resource-Based Cities: The Case of Benxi

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Resource-based cities, which emerge due to the large-scale industrialization of China, mainly rely on local natural resources for industrial layout and economic development. However, resources have been gradually exhausted due to overuse, resulting in a series of negative impacts on the environment and resources. In order to realize long-term sustainable development and avoid falling into the "resource curse," measures such as industrial structure adjustment and technological upgrading to promote the transformation of these cities ought to be implemented. Taking Benxi, one of the most typical mineral resource-based cities in China, as an example, this study discusses the economic and environmental performance and existing problems in the local transformation process, comparing it with successful transformation patterns of global mineral resource-based cities. On this basis, a series of policy suggestions together with possible ways toward sustainable development are put forward and summarized.

Keywords: resource-based cities, Benxi, transformation, sustainable development, resource curse

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INTRODUCTION

Resource-based cities refer to those with mining and natural resources processing as the leading industries (The State Council of the PRC, 2013). The emergence and development of such cities are inseparable from industrialization. Up to now, there are 126 prefecture-level and 120 county-level resource-based cities in China. Relying on rich resources such as energy and minerals, these cities have become China's industrial bases and contributed to China's economic development. In recent years, however, continuous promotion of resource development and gradual depletion of resource reserves have led to severe overcapacity of steel, cement, glass, and other resource products. Many resource-based economies have encountered difficulties or even recession in urban development, manifested as environmental degradation and economic decline. On the one hand, compared with other non-resource-based economies, resource-based economies are facing more severe resource exhaustion and environmental deterioration (Wang and Chen, 2020), such as the increasing shortage of forest resources, land resources, and water resources, as well as excessive emissions of air pollutants. On the other hand, due to their single industrial structure, the economic growth is weak (Auty, 1994; Torvik, 2002), which will push up the poverty rate and unemployment rate. In addition, the excess profits of the resource industry will exacerbate income inequality and lead to some social problems (Ali et al., 2020). Abundant resources are likely to hinder economic growth and lead to the problem of the "resource curse". Once such a problem appears, it will significantly affect the sustainable development of cities and bring high governance costs (Sachs and Warner, 1995). Therefore, resource-based regions must actively promote the industrial structure transformation in order to reduce the over-reliance on resources, seek new growth power, and then in turn fully meet the requirements of sustainable and high-quality development in the new era (Long et al., 2020). In

this regard, the consensus has been reached around the world, with a series of transformation means, including innovation orientation, talent attraction, and environment protection having been put forward (Papyrakis and Gerlagh, 2004; Du et al., 2012; Du et al., 2020; Li and Long, 2020).

However, although the problem of the "resource curse" and the solutions to it are heated topics in research on the environment and resources, little attention has been paid to the economic and environmental impact of the "resource curse" at the city level, especially in the conditions of those resource-based cities in China. Also, gaps in the existing research, which mainly concentrates on academic theories of the mechanism of the "resource curse," have limited our understanding of specific city transformation patterns and practical policies.

Benxi, located in the southeast of Liaoning province, is an important industrial city in China, with a population of over 1.3 million and a GDP of 81 billion RMB in 2020. Benxi is rich in mineral resources and takes the iron and steel industry as its pillar industry. During the 1950s–1990s, when China vigorously developed the secondary industry, the social economy of Benxi achieved rapid development. However, due to the overuse of resources, it gradually faced double pressure on the economy and environment after entering the 21st century (Li and Zou, 2018). Though a series of policies have been issued in an attempt to solve the problem of the "resource curse," little progress has been made. Therefore, effective measures to promote the transformation are awaited.

This study chose Benxi as a typical case to study the resource-based cities in China for the following reasons. First, since Benxi was positioned as a mature resource-based city in The National Sustainable Development Plan for Resource-Based Cities (2013-2020) issued by the State Council of the PRC, it is necessary to reveal the environmental performance and economic developments in its transformation process. Second, as Benxi is an important industrial city in Liaoning province, clarifying the focus and direction of transformation is meaningful to the sustainable development of the old industrial bases in Northeast China. Finally, Benxi is a representative of many resource-based cities in China. A feasible transformation path is significant and provides a valuable reference for the high-quality development of all such cities in China.

This study, therefore, analyzes the environmental and economic performance of Benxi, briefly explains the mutual relationship, and summarizes reasonable approaches to promoting its sustainable development through the comparison of successful transformation patterns from resource-based cities across the world, aiming to provide policy implications for the transformation of such cities in China.

ANALYSIS OF THE ECONOMIC AND ENVIRONMENTAL PERFORMANCE OF BENXI

In the past, resource-based cities and old industrial cities in China, such as Benxi, developed their economies rapidly through the flourishing secondary industry, which caused severe negative impacts on the environment. At the same time, it is accompanied by severe consumption and rapid depletion of resources. Since the secondary industry, especially the mineral resource industry, is the main pollution source, this study analyzes the environmental and economic performance and focuses on the effect generated by the mineral industries and the defects inherent in such industries. Furthermore, governments ought to intervene in developing such industries through policy means, in order to achieve the goal of transformation and sustainable development.

Economic Performance: The "Steel-Dominated" Economic Model

The economic structure of Benxi is mainly dominated by the secondary industry, especially the iron and steel industry, and the chemical industry. As presented in **Figure 1**, the output value of the iron and steel industry accounts for more than 80% of the city's total industrial output value. As the pillar industry of Benxi, this industry has made significant contributions to the economic and social development of Benxi, which served as the momentum of economic growth and created tens of thousands of jobs for Benxi.

Benxi has implemented policies to boost its economy and reduce its reliance on resources in recent years. First, it emphasizes the development of the tertiary industry. As shown in **Figure 2**, the tertiary industry has gradually occupied the leading position in the industrial structure, with the importance of the service industry becoming increasingly prominent since 2011. In terms of the secondary industry, aiming at changing the situation of "steel dominating," Benxi has established several industrial clusters other than the iron and steel industry successively, including the biomedical industry cluster, advanced material industry cluster, glass product industry cluster, and packaging and printing industry cluster, which support each other and develop in multiple ways.

Although Benxi has taken a series of measures, problems existing in the industrial structure have not been fundamentally changed. Even though the proportion of the tertiary industry exceeded that of the secondary industry for the first time in 2016, the secondary industry regained its advantage over the tertiary industry in 2019, which implies that the service industry of Benxi lacked growth momentum. Moreover, as for the secondary industry, the proportion of the output value of the iron and steel industry in the total industrial output value has even risen to more than 80% (see **Figure 1**). Also, for those not so relevant to mineral resources, the compound annual growth rate (CAGR) from 2016 to 2020 of industries that have already taken shape (e.g., the pharmaceutical manufacturing industry) is significantly lower than the average, while industries with a higher CAGR have suffered from their small scale (**Figure 3**). The reason behind the situation is that *Bensteel Group*, the largest enterprise in Benxi, has been set as the core and leader of Benxi's industry and tilted many resources. Although Benxi has strived to construct several industrial clusters other than the iron and steel industry, it inevitably lays out

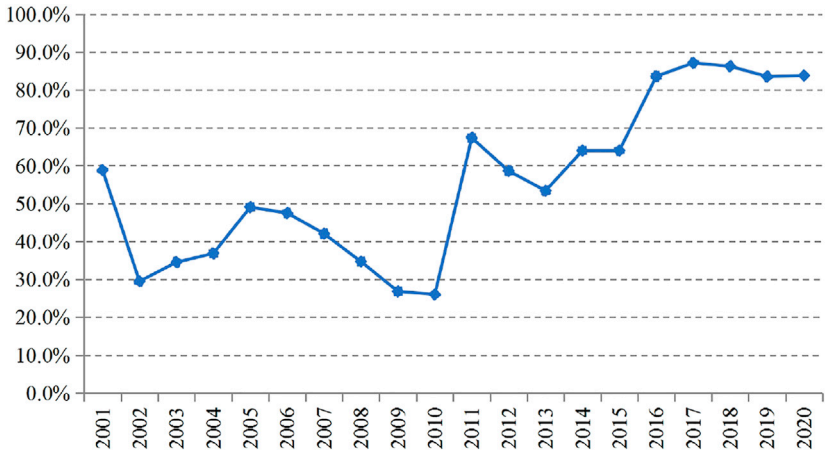

FIGURE 1 | Output value of the iron and steel industry. Data source: Benxi Statistical Yearbook, 2001-2020.

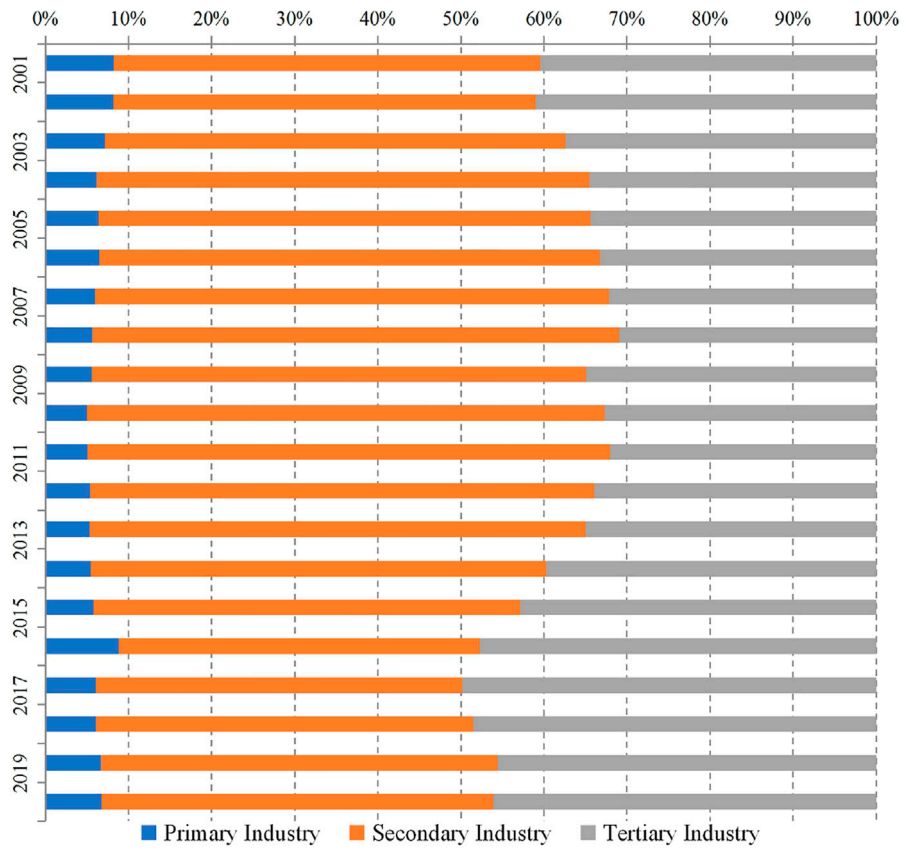

FIGURE 2 | Industrial structure, Benxi, 2001-2020. Data source: Benxi Statistical Yearbook, 2001-2020.

industrial clusters around *Bensteel Group* due to the path dependence supporting the development of pillar industries. Therefore, the tertiary industry and other sectors of the secondary industry are facing limited resources, sluggish development, and heavy reliance on resources.

In addition, due to the lack of a fine business environment and educational resources in Northeast China, it is difficult for Benxi to attract and retain professionals. Furthermore, the severe aging population structure also restricts its long-term sustainable development (in 2020, the population over 60 years old in

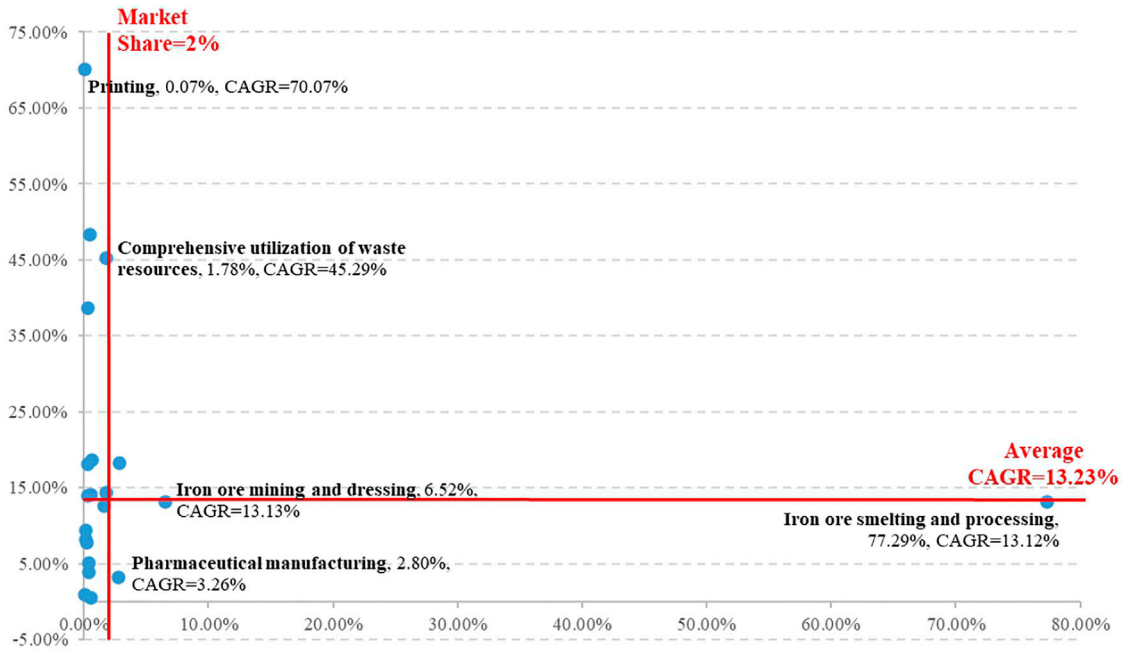

FIGURE 3 | Boston matrix of industrial output value, Benxi, 2016-2020. Data source: Benxi Statistical Yearbook, 2001-2020

Benxi accounted for 29.01% (national average 18.7%), and over 65 years old accounted for 19.11% (national average 13.5%)).

Environmental Performance: Severe Pollution Caused by the Steel Industry

The secondary industry, especially the steel industry, has long been the root cause of the environmental problems of Benxi. For example, the proportion of industrial waste in total waste is around 40%, while the provincial average is around 15%. Over the years, by implementing measures that selected Benxi as a national demonstration city for the construction of ecological civilization and defined this city as an "important water conservation area, the 'hinterland' of ecological security, and the ecological 'barrier'" of Liaoning province, Benxi has made some achievements in environmental protection. For example, in 2020, the number of days above grade II (good) ambient air quality in the city was 319, while 274 in 2015. The total emission of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) has decreased compared with the situation in the past, the same as the wastewater emission from the iron and steel industry.

Nevertheless, the progress of the transformation is not satisfactory, and the pressure on resources and environmental protection is still severe. As the mineral resources industry is still vital, coupled with the needs for agricultural planting and road construction, the pressure on land and water resources is huge, and the ecological functions such as forest water conservation, hydrological regulation and storage, and biodiversity protection continue to decline. The industrial structure dominated by iron and steel with high energy consumption and high emission will be maintained for a long time. For instance, in 2020, the average dust content in the air was 8.4 t/(km^2·month), 0.4 t/(km^2·month) higher than the provincial standard. The energy consumption per unit of GDP did not meet the provincial standard. The total emission of carbon dioxide and major significant pollutants was still high, with *Bensteel Group* accounting for 84.3%. Among them, the emission of SO_2 and NO_x is prominent. In 2020, the annual average emission concentrations of SO_2 and NO_x were 17 μg/m^3 and 30 μg/m^3, respectively. Moreover, the PM 2.5 concentration in 2020 was 37 μg/m^3. It did not reach the national average level of 30 μg/m^3 in that year, and it was also far from that of well-performed industrial cities in China. In addition, as the main source of solid waste (accounting for 19.5% of the city's output), the average utilization rate of the iron and steel industry is only 24%, which is far lower than the national average. Current situations indicate that the mineral industries and products in Benxi can be characterized as inefficient, resource-consuming, and not so environment-friendly. The low level of science and technology in the mineral industries led to such problems. Furthermore, this is why none of plenty of those existing treatments can make a substantial difference to the conditions of the environment and resources.

Summary

The analysis of the current situation of Benxi shows that the path of giving priority to heavy industries with high resource consumption and high pollution frustrates the development of Benxi, together with its efforts to solve the crux of the "resource curse." More specifically, the deep reliance on *Bensteel Group* and the inability to promote environment-friendly production due to the low level of science and technology cause Benxi's difficulties in both environmental and economic aspects and hinder the

TABLE 1 | Three patterns of transformation of mineral resource-based cities.

	Pattern	Similarities	Difference
Type I ***Kawasaki, Japan***	Transforming to an innovative city based on traditional industries	1. Form **a diversified industrial structure** integrating manufacturing and services 2. Develop **high-tech industries** (new materials, biomedicine, environmental protection, and information technology.)	**Retain** the mineral resource industry
Type II ***Ruhr Region, Germany***	Taking the strategy of new industrialization based on traditional industries	3. Improve **urban service functions** (leisure, entertainment, culture, tourism, medical treatment, and education.) 4. Strengthen **environment protection**	**Reduce** the mineral resource industry
Type III ***Pittsburgh, US***	Transforming to a city of "green, science, and high-tech" and abandoning traditional industries	5. Combine **colleges and universities** with the local economy 6. Stimulate the development of **small- and medium-sized enterprises**	**Abandon** the mineral resource industry

The bold values provided in Table 1 are the things we want to emphasize, i.e., keywords in the similarities and differences.

transformation process. Therefore, there is still a long way for resource-based cities such as Benxi to fully realize their transformation goals and sustainable development and numerous effective policies on green development, such as giving impetus to clean production and setting more stringent emission standards, are urgently needed.

COMPARISON OF PATTERNS OF TRANSFORMATION AND POLICY IMPLICATIONS

Policy Experience From Three Patterns of Transformation

The development of the mineral resources of Benxi has impacted its environment a lot. A series of policies issued by the local government have effectively promoted the city's transformation. However, there is still a big gap between the policy effect of Benxi and the advanced level as optimizing the industrial structure is the fundamental way to form high-quality development. The problems faced by global mineral resource-based cities similar to Benxi have tried to transform. Among them, the transformation of Kawasaki in Japan, Ruhr in Germany, and Pittsburgh in the United States were successful. This study summarizes the policies experienced in the three cities mentioned earlier in their transformation processes (see **Table 1**).

Kawasaki is a representative of "Retaining the mineral resources industry." The city has gradually evolved from a steel manufacturing city to one composed of a highly developed service industry and technology-intensive industries. This city upgraded its technology gradually and made full use of the original market demand, which designed more research and development (R&D) bases for new materials and environmental industries based on retaining the iron and steel industries and chemical industries. By transforming the past manufacturing plants into the core R&D bases of enterprises, Kawasaki constructed high value-added and knowledge-intensive industries, cultivated small- and medium-sized enterprises, and turned the small- and medium-sized enterprises that had originally provided support for transforming large enterprises into enterprises with R&D capabilities.

Ruhr Industrial Zone is a world-famous heavy industry base. Its transformation focused on "Reducing the mineral resources industry" and was committed to implementing "new industrialization." Compared with the pattern of Kawasaki, it emphasized developing and diversifying traditional industries upstream and downstream of them. In this pattern, new technologies comprehensively changed traditional industries, and high-tech industries such as the information technology industry rose. At the same time, the upstream and traditional downstream industries have made significant progress. Industries such as real estate, electronic systems, technical consulting, and service trade developed successively, absorbing the unemployed labor force from the coal and steel industries. It is worth mentioning that higher education in the Ruhr district is closely combined with economic development, industry, university, and research deeply integrated, which has promoted the improvement of technological innovation and further stimulated the transformation of the industrial structure.

Pittsburgh has transformed from "the steel capital of the world" to "the most livable city in the US." This process of "abandoning the mineral resources industry" supported by education is remarkable. Pittsburgh has achieved a comprehensive transformation from a single steel industry to a diversified economy, including biotechnology, computer technology, machine manufacturing, education, medical treatment, tourism, and finance. Relying on two prestigious universities, the University of Pittsburgh and Carnegie Mellon University and their disciplinary advantages in medicine and computers, the city has vigorously developed emerging technology industries such as biomedicine, information communication, and new materials. The city has constructed a complete technology transformation mechanism, and has promoted the financial market represented by venture capital. Also, when having its secondary industry reformed, Pittsburgh attached great importance to education, life, leisure, and infrastructure construction simultaneously to produce more employment opportunities and promote the overall improvement of urban quality.

To summarize, there are many dimensions to the implications of the transformation of resource-based cities according to the three patterns. Measures to adjust the economic structure to avoid a dominant industry, boost innovation and the development of science and technology, promote environment-friendly industries, improve public services in cities, and preserve the environment need to be implemented.

Actionable Recommendations for Benxi

It is necessary to apply the merits of the three patterns to the transformation of China's mineral resource-based cities. The policy suggestions in terms of the current economic and environmental performance of Benxi to shield the city from being troubled by the "resource curse" and promote its sustainable development are provided as follows.

First of all, Benxi should consider promoting the construction of technology-intensive and environment-friendly industries. The newly arranged industrial clusters in Benxi may be incapable of supporting its sustainable development. For example, the packaging and printing industrial cluster is difficult to contribute to the potential long-term stable growth of Benxi, and this industry will still have a negative impact on the environment. The entry of local high-tech industries can better promote the TFP and economic growth (Barro and Lee, 1994; Yang and Wang, 2004) with greater environmental performance. Therefore, under the goal of sustainable development, Benxi should vigorously promote the construction of technology-intensive and environment-friendly industries, such as new materials, new energy, environmental protection, and other industries (Wei et al., 2022). For the iron and steel industry, Benxi ought to scientifically regulate and control the iron and steel output, focus on reasonably predicting the output in combination with the relevant requirements of waste gas emission and environmental capacity, and pay attention to strengthening energy management and green production research and development (Wei et al., 2021). A gradual reduction in reliance on the steel industry should also be considered.

Second, Benxi should be committed to improving the urban service functions and service attributes. Benxi still retains its obvious characteristics as a traditional industrial city. Although the proportion of the service industry is gradually increasing, the urban service function is still limited, not to mention the underdeveloped higher education. Therefore, Benxi should emphasize improving urban service functions and service attributes, especially the development of scientific research and education, cultivation of research bases, and combination of primary and higher education with local economic development. In addition, environmental renovation can also be used to expand the city's leisure functions, such as constructing landscape parks and developing shopping tourism (e.g., Industrial Heritage Tourism).

Last but not least, Benxi ought to assist in developing small and medium-sized enterprises and provide diversified and efficient supporting policies. The current industrial pattern of Benxi City regards *Bensteel Group* as the core. The leading enterprise has monopolized the input from Benxi, which may erode the growth space of other enterprises and industries. The existence of super-large enterprises may also affect the allocation of labor share (Autor et al., 2020). In this case, Benxi is supposed to support the development of small- and medium-sized enterprises, weaken the financing and policy barriers restricting their development, and focus on cultivating several small- and medium-sized enterprises with R&D capacity to add more vitality to the process of economic development and transformation.

CONCLUSION

Resource-based cities can often face the "resource curse" after mature development. The transformation of the industrial structure is the only way to realize both economic and ecological benefits and achieve sustainable and high-quality development. As a typical mineral resource-based city, Benxi has further optimized its environment and significantly improved its industrial structure by implementing economic and environmental policies. However, some problems have not been solved yet. Compared with the three successful transformation cases of mineral resource-based cities worldwide, the local transformation effect needs to be improved. Therefore, relevant policies should be upgraded by concentrating on innovation and the high-tech industry's development and deeply combining education with industry in the three cases. As for Benxi's case, its excessive dependence on the iron and steel industry has eroded the development space of emerging industries. The negative impact of high energy consumption and emissions on environmental resources persists and has not been fundamentally improved. Under such circumstances, this study puts forward a series of suggestions, including vigorously building technology-intensive and environment-friendly industries, reasonably regulating the output of iron and steel, focusing on developing science and education, and supporting small- and medium-sized enterprises. This study aims to provide a possible path for Benxi's transformation and the transformation and high-quality development of resource-based cities in China and even the world.

AUTHOR CONTRIBUTIONS

HL conceived of the idea and outlined the brief. XW collected data and wrote the first draft of the article. HL and ZC made important modifications to the brief. All authors contributed to article revision and have both read and approved of the submitted version.

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