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How does the National Key Ecological Function Area policy affect the upgrading of the industrial structure?—based on the examination of the Yellow River Basin in China

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The transformation and upgrading of the industrial structure constitute a pivotal task for sustainable economic development, and the factors influencing this process are also of concern to developing countries around the world. Unfortunately, there is still relatively little systematic discussion on the impact of environmental policy on the industrial structure. Against this backdrop, we have employed the multi-period differences-in-differences (DID) model to assess the impact of the implementation of the National Key Ecological Function Area (NKEFA) policy on the industrial structure in the Yellow River Basin. Our findings reveal that this environmental policy fosters the advancement of industrial structure but does not influence its rationalisation. Regarding mediating effects, we confirm the positive impacts of population density and the investment in education. Furthermore, the policy effects are more pronounced in non-ethnic provinces with better basic conditions, whereas ethnic provinces exhibit almost no effect. The policy effects are more significant in large cities than in small and medium-sized cities. These findings enrich the existing exploration of the impact of environmental policy on industrial structure and provide a strong reference for policy practice in developing countries.

KEYWORDS

national key ecological function areas, industrial structure, policy effect, Yellow River Basin, environmental protection

1 Introduction

Worldwide economic growth through industrialisation is a consistent and prominent phenomenon. However, this growth has placed significant pressure on global energy resources and the environment, as evidenced by numerous studies (Cheng et al., 2019; Dong B. et al., 2020; Zhao et al., 2021). In response, the adjustment of the industrial structure is a shared concern among all countries, representing a sustainable path to achieving low-carbon development (Zhao et al., 2020; Ren et al., 2021). For China, promoting economic modernisation and pursuing high-quality development are crucial objectives. Among various initiatives, the optimisation and upgrading of the industrial structure stand out as key components (Dong

K. et al., 2020). The realisation of economic growth must be supported by industrial upgrading. China is transforming from the era of industrialisation to the era of knowledge (Liang and Yang, 2019). After a period of effort, the industrial structure has transitioned from being dominated by manufacturing industries to being led by high-tech sectors. However, from the perspective of the regional industrial future, challenges such as uncoordinated element configuration and a low industrial level still persist (Ma, 2023). How to adjust and optimise the industrial structure to help the regional economy develop in a sustainable and coordinated way is an arduous task for developing countries (Ren and Huang, 2021).

To address these concerns, China initiated two rounds of National Key Ecological Functional Area (NKEFA) policy pilots in 2010 and 2016, encompassing numerous initiatives related to industrial adjustment. China emphasised its commitment to firmly implementing this policy in the future, recognising it as a crucial step in the construction of an ecological civilisation (Xu et al., 2018). The policy is intricately linked to national regional ecological security and aims to regulate industrialisation and urbanisation in the development of the national land space (Chen et al., 2024). It also introduces new provisions for industrial development. In line with the principles of ecological function restoration and conservation, the region must enact more targeted industrial access policies and standards, elevating the industrial threshold for various development projects. Furthermore, the policy recommends that these regions maintain and enhance their ability to supply ecological products. Consequently, this will inevitably result in a reshaping of the regional industrial structure.

The Yellow River Basin, an important economic hub and ecological protection barrier in China, has garnered considerable attention for its industrial structure upgrading and ecological protection efforts (Guo et al., 2022). The development of the Yellow River Basin faces many constraints (Liu et al., 2016). It is crucial to assess whether the implementation of the NKEFAs can effectively alleviate these challenges. At present, there are cases showing that the policy has helped upgrade the industrial structure in the Yellow River basin. For example, Yangquan, as a prefecture-level city in the Yellow River basin, has made remarkable achievements in the construction of NKEFAs. Through measures such as the restoration and treatment of abandoned mines, comprehensive improvement of the ecological environment, domestic sewage treatment, and garbage classification, Yangquan has not only improved the quality of the ecological environment but also vigorously promoted the upgrading and development of the new energy industry. Therefore, a comprehensive discussion of policy effects will help solve the practical problems in the Yellow River Basin and provide demonstration effects and promotion experiences for other regions.

The research significance of this study is evident on both theoretical and practical fronts. At the theoretical level, through empirical analysis, we can explore how NKEFAs promote the optimisation and upgrading of the industrial structure through influencing factors such as resource allocation, technological innovation, and market demand. It can enrich the existing theory of industrial structure upgrading. At the practical level, the Yellow River Basin is one of the important economic regions in China, and the upgrading of its industrial structure is of great significance to promote the coordinated development of the regional economy. At the same time, the policy implementation also faces the heterogeneity among regions, and this study will provide new ideas for this.

The innovation of this paper lies in its in-depth exploration of the relationship between environmental policies and industrial structure. Furthermore, in the mediating mechanism test, we incorporate the effects of talent cultivation and spatial dynamics induced by environmental policies into our framework, confirming their significance. This is something that has not been considered before. Finally, in terms of heterogeneity analysis, this study is the first to explore the specific differences between ethnic and non-ethnic provinces in China. This not only aligns more closely with the actual situation in China but also provides a fresh ethnic perspective for related research. We conduct systematic experiments on some of the above elements, contributing to a more comprehensive understanding of the policy's impacts.

2 Literature review

2.1 Effect of the policy on the upgrading of the industrial structure

A policy is an important tool for influencing the industrial structure. The first is the industrial policy (Chen and Xie, 2019). For example, cases from South African countries show that industrial policies can stimulate production dynamics and enhance productivity, which leads the industrial structure in a more efficient direction. In the time dimension, the extent of the impact will gradually deepen (Craig, 2015). At the same time, it is worth pointing out that there is a strong correlation between the adequacy of industrial policy and its effectiveness. When policies are not adequately implemented, there may even be an impediment to industrial structure upgrading (Vrolijk, 2021). This is particularly evident in an underdeveloped economy. Second, some studies have suggested promoting industrial structure upgrading through financial policies and have made a theoretical mechanism description (Zou et al., 2024).

For policies affecting the industrial structure, environmental regulations cannot be ignored, but there are still controversies about their role. Some argue that environmental regulations are beneficial for industrial structure upgrading (Chen et al., 2022). On the contrary, others argue that the impact is constrained by the stringency of environmental regulations (Shen et al., 2020). Some studies from China also demonstrate the heterogeneity of environmental policies across different levels of economic development (Du et al., 2021; Zhang et al., 2019). The NKEFA policy is an influential environmental policy implemented in China, and its effect on industrial structure upgrading is currently neglected.

2.2 Factors affecting the upgrading of the industrial structure

Numerous studies have been conducted to explore the factors affecting industrial structure upgrading. These influencing factors include financial development, urbanisation level, foreign trade development, information technology advancement, and infrastructure construction. Specifically, financial development will act on industrial technology, and this transmission path ultimately affects the industrial structure (Zou et al., 2024). In turn, increased urbanisation will promote industrial structure transformation by aggregating and integrating resources. However, there have been studies further extended and found that the positive impacts brought by urbanisation are not lasting (Lin et al., 2018). In addition, the growth of information technology has led to the emergence of the information industry, prompting scholars to examine its contribution to the industrial structure. Several research results have revealed the positive effects of information technology to a certain extent (Xu et al., 2022). There are two conflicting views on the impact of foreign trade development on industrial structure upgrading. Some studies argue that foreign trade ultimately has little impact on the industrial structure (Zhou and Chen, 2022). However, there are also scholars who say that the development of foreign trade can affect the industrial structure through channels such as the international division of labour and undertaking industrial transfer from developed economies (Franke and Kalmbach, 2005). The role of infrastructure development in upgrading industrial structure seems to be more obvious, both in terms of transport network development and expansion of transport capacity, which are more favourable to industrial development (Lin et al., 2023). At present, there is still a lack of discussion on factors such as population density and education investment, which will be supplemented by the intermediary mechanism in this paper.

2.3 Related research on the Yellow River Basin

Discussions on the Yellow River Basin have mostly centred on two major aspects, namely, ecological environment and economic growth (Liu et al., 2021; Wang and Tan, 2021). In this regard, academics have mostly used descriptive statistics or threshold effect models to report on development situations and the problems related to regional factors (Qiu et al., 2021) or the impact of economic development on a single element of the ecological environment. This is particularly true for water resource supply and carrying capacity, water pollution prevention, and soil environmental protection (Chen et al., 2023). Scholars have also systematically examined the Yellow River Basin in terms of the trade-off between the environment and economy (Xue and Liu, 2023). However, there is a lack of exploration into the application of NKEFAs in the region and their capability to influence the industrial structure.

In summary, existing studies have made significant contributions to laying the theoretical and practical foundation for this paper. However, overall research on the impact of environmental policies on the industrial structure is relatively scarce and still debated. Furthermore, this study will provide new case evidence.

3 Theoretical mechanisms and research assumptions

NKEFAs serve as pivotal guidelines for industrial development, emphasising the preservation of the environment throughout the construction process. Policy areas within industrial development planning, productivity layout, etc., are expected to lead the allocation of resource elements and the formulation of industry-specific planning (Gong et al., 2021). Therefore, the implementation of the policy will contribute to the upgrading of the industrial structure to a certain extent. The upgrading of the industrial structure includes the advanced industrial structure (AIS) and the rationalisation of the industrial structure (RIS) (Xue et al., 2022). The specific mechanism of policy implementation can be expanded into two aspects.

3.1 NKEFAs can promote the AIS

First, NKEFAs clearly restrict the large-scale and high-intensity industrialisation and urbanisation development in these areas, thus limiting the development of high-pollution and energy-consuming industries.

Second, the policy fosters and endorses the development of green, low-carbon, and environmentally friendly industries, such as clean energy and energy-saving technologies. The establishment of special industrial development funds, tax incentives, and other measures encourages enterprises to increase their investment in green technology innovation and promotes the development of the industrial structure in the advanced direction.

Third, the policy advocates accelerating the revolution in energy production and consumption and increasing the proportion of renewable energy sources in the energy mix. This will help reduce dependence on traditional energy sources, reduce carbon emissions, and promote the upgrading of the industrial structure.

3.2 NKEFAs can promote the RIS

On one hand, the policy strengthens the supervision and assessment of the ecological environment and establishes the long-term mechanism for a comprehensive assessment of regional ecological functions. This helps discover and solve ecological and environmental problems, ensure that the adjustment of the industrial structure meets the requirements of ecological and environmental protection, and realise the rationalisation of the industrial structure.

On the other hand, the policy guides the flow of resource elements to industries that meet the requirements of ecological environmental protection through industrial regulation and project layout. This will help realise the rational allocation of production factors and promote the rationalisation of the industrial structure. In line with these considerations, we propose Hypothesis 1.

Hypothesis 1. NKEFAs can promote the upgrading of the industrial structure in the Yellow River Basin.

NKEFAs impose stringent restrictions on various development activities within the region with the goal of diminishing the footprint of human endeavours and promoting greater utilisation of space for ecosystem circulation (Lin et al., 2020). Consequently, a decline in population density is inevitable. Population density, denoting the number of people per unit area, serves as a crucial indicator reflecting population distribution in cities, regions, or countries.

Reducing population density will promote industrial upgrading, and the theoretical logic can be expanded into two aspects.

3.3 Reducing population density can promote the AIS

On one hand, high population density can inhibit innovation. In high-density population areas, due to fierce competition and high survival pressure, enterprises and individuals may be more inclined to pursue short-term interests while ignoring long-term technological innovation and research and development investment. Reducing population density can help ease this pressure, providing a more relaxed environment for businesses and individuals to innovate. At the same time, lower population density may also promote the flow of talent and knowledge exchange, provide more diversified ideas and resources to support innovative activities, and thus promote the upgrading of industrial structure.

On the other hand, the NKEFA policy is usually implemented in areas where the ecological environment is more sensitive or fragile, and the environmental carrying capacity of these areas is limited. Reducing population density can help reduce the pressure on the ecological environment and protect the stability and integrity of the ecosystem. With the improvement and restoration of the ecological environment, these areas will be more likely to attract the settlement and development of high-tech and high-value-added industries, thus promoting the upgrading of the industrial structure.

3.4 Reducing population density can promote the RIS

Reducing population density helps balance development among different industries. In high-density population areas, due to limited resources and fierce competition, some industries may overdevelop and neglect the coordinated development of other industries. By reducing population density, the situation of resource monopoly and competition imbalance can be addressed, and more equitable development opportunities and space can be provided for different industries. This will help form a diversified industrial structure system and achieve balanced development among industries.

To sum up, reducing population density can promote the upgrading and rationalisation of the industrial structure through multiple aspects such as optimal allocation of resources, innovation-driven initiatives, consideration of environmental carrying capacity, balanced industrial development, market regulation, and improvements in social welfare. This hypothesis not only aligns with theoretical logic but also provides strong theoretical support for the development of empirical research (Acemoglu et al., 2018; Pipkin and Fuentes, 2017). By analysing the impact of population density, we propose Hypothesis 2.

Hypothesis 2. NKEFAs can promote the upgrading of the industrial structure by reducing population density.

In addition to reducing population density, NKEFAs can increase education investment. First, the establishment of NKEFAs is geared towards safeguarding and restoring the ecological environment. This imperative necessitates increased investment in education to offer more theoretical programs and cultivate talent dedicated to ecological environmental protection. Second, China has consistently elevated subsidies for eco-protected areas, demonstrating a growing commitment to financial support with a focus on enhancing public services within eco-zones. This endeavour extends to improving public cultural conditions, elderly care services, and education services in urban areas. In the realm of education, this commitment is reflected in an additional annual increase supplementing the existing education funding policy, resulting in an augmented proportion of subsidies for public education funding. Investment in education promotes the upgrading of the industrial structure mainly lies in the following aspects.

3.5 Investment in education is beneficial to the AIS

On the one hand, educational input provides high-quality personnel. Investment in education can improve the overall quality and skill level of the labour force and cultivate more talents with advanced skills and innovative capabilities. These talents are the core force of technological innovation and industrial upgrading and an important basis for promoting the advanced industrial structure.

On the other hand, educational input promotes research, development, and application of technology. The increase in educational investment helps enhance the research capacity of scientific research institutions and universities and promotes the development and application of new technologies and processes. The application of these new technologies and processes can improve the technical content and added value of the industry.

3.6 Investment in education is beneficial to the RIS

On one hand, investment in education promotes industrial diversification. Increasing investment in education can cultivate more talents with diversified skills and knowledge, which can adapt to the needs of different industrial sectors and promote the diversified development of industries. The diversified development of industries helps enhance the anti-risk ability and sustainable development ability of the economy so as to promote the RIS.

On the other hand, educational input optimises the layout of the industrial structure. The increase in education investment can also guide the flow of labour to industrial fields with more development potential, thus optimising the layout of the industrial structure. The optimisation of this layout helps improve the utilisation efficiency of resources, reduce the waste of resources and excessive competition, and promote the rational development of the industrial structure.

Hypothesis 3. NKEFAs can contribute to the development of the industrial structure by increasing investment in education.

The Yellow River Basin encompasses both ethnic and non-ethnic provinces, exhibiting substantial economic disparities between them. Various factors contribute to these differences, including location, historical background, religion, and culture. In terms of location factors, ethnic provinces lag behind in terms of transportation conditions, communication infrastructure, and other facilities due to the complexity of their geographical environment. Regarding history and culture, most ethnic provinces face challenges in educational resources, impacting talent development. These factors distinguish ethnic provinces from others in terms of the regional economy, and the industrial structure of ethnic provinces tends to favour traditional industries, potentially affecting policy effectiveness.

Research on the scale of cities and spatial agglomeration of industries has a long history. It is widely acknowledged that achieving industrial diversification and clustering is challenging in small cities compared to large cities (Dai et al., 2022). The primary reason for this lies in the generally larger market size of large cities, resulting in higher market demand. Moreover, factors such as talent and capital are more likely to be concentrated in larger cities. Consequently, large cities have a better foundation for developing industrial structures, lower communication and transport costs within and between industries, and more efficient division of labour among different sectors. As a result, policy effects vary across different city scales.

Hypothesis 4. The effect of the policy is heterogeneous in ethnic and non-ethnic areas and cities of different sizes.

4 Methodology and data

4.1 Econometric modelling

The multi-period differences-in-differences (DID) method is gaining favour. This is because it deals well with the issue of endogeneity in conducting the policy assessment process. Moreover, the problem of omitted variable bias is mitigated to some extent by the use of fixed effects estimation (Wang and Watanabe, 2019; Chagas et al., 2016). At the same time, the DID approach, which typically requires the use of panel data, is able to more fully capture changes. Due to the need to assess the impact of a specific policy on the upgrading of the industrial structure, the DID method becomes a very suitable choice. By setting up the treatment group and the control group scientifically and comparing the differences before and after the implementation of the policy, the actual effect of the policy can be accurately evaluated.

Because the pilot areas were approved to be established at different times, a multi-period DID was chosen to estimate the impact. We select 85 cities as a sample and measure them using panel data from 2007–2019. The benchmark model settings are shown as Equation 1:

$$Y_{it} = \alpha + \beta DID_{it} + \delta X_{it} + \mu_i + \gamma_t + \varepsilon_{it}. \tag{1}$$

Y_{it} is a measure of industrial structure upgrading in city i in period t and DID_{it} denotes the shock of the policy pilot, where pilot cities are the disposal group and non-pilot cities are the control group. In addition, α is a constant term; β and δ are parameters to be estimated; X_{it} represents time-varying control variables; μ_i represents city fixed effects; γ_t represents fixed effects for the corresponding year; and ε_{it} represents random error terms.

4.2 Research area and data sources

Due to the difficulties of data collection in some cities, incomplete records, or abnormal values, noise is introduced into statistical analysis, which affects the accuracy and reliability of the results. At the same time, there are significant differences between some cities in terms of economic development level, industrial structure, and resource endowment. These differences may result in different response mechanisms during the implementation of NKEFAs, thus affecting the accurate assessment of the overall effect. Finally, we excluded the cities with the above-mentioned problems, such as Bayannur, Ya'an, Tai'an, Weihai, and Yantai.

We selected a sample of 85 cities in 9 provinces in the Yellow River Basin. There are 41 cities in the experimental group and 44 cities in the control group. In the experimental group, 30 pilot cities were established in 2010 and the remaining 11 were established in 2016. We use data for 3 years before and after the policy implementation, so the panel data range is 2007–2019.

All the data come from the China Urban Statistical Yearbook, China Tertiary Industry Statistical Yearbook, China Urban and Rural Construction Statistical Yearbook, China Population and Employment Statistical Yearbook, and economic and social development statistical bulletins. The data sources selected covered the main variables needed for the study in order to conduct a scientific empirical analysis. The above-mentioned statistical yearbooks and communiques contain a wealth of economic, social, demographic, and employment data, which are closely related to the upgrading of the industrial structure and can comprehensively reflect the changes. As official statistical publications, these data sources are highly authoritative and official, ensuring the accuracy and credibility of the data.

4.3 Description of variables

4.3.1 Explained variables

The explained variable in this paper is industrial structure upgrading, which can be split into two parts, namely, AIS and RIS. AIS is mainly reflected in the specialised division of labour in society (Jin, 2007) and is mainly measured by constructing the industrial structure hierarchy coefficient in this paper, as shown in Equation 2.

$$AIS_{it} = \sum_{m=1}^{3} \left[\left(G_{itm} / G_{it} \right) * m \right]. \tag{2}$$

In a number of current studies, the Thiel index has been used predominantly as a persuasive measure of the RIS (Li et al., 2021). We still draw on this method to calculate the RIS, which is measured using the following equation, as shown in Equation 3.

$$RIS_{it} = \sum_{m=1}^{3} G_{itm} / G_{it} \ln\left[\left(G_{itm} / L_{itm} \right) / \left(G_{it} / L_{it} \right) \right]. \tag{3}$$

m represents primary, secondary and tertiary industries, respectively. G_{itm}/G_{it} denotes the share of industry m in GDP. L_{it} is the number of employed persons.

4.3.2 Explanatory variables

In December 2010, the NKEFAs delineated the first batch of pilot areas, followed by a new batch in 2016. The core explanatory variable of this paper is the NKEFA policy shock (DID_{it}). That is, when city *i* has the qualification of being approved as a pilot area in year *t*, then DID_{it} is assigned a value of 1 for city *i* in year *t* and the subsequent years; otherwise, it is 0.

4.3.3 Controlled variables

We considered a number of controlled variables to reduce data bias in the experiment. The share of retail sales of consumer goods in GDP is more direct data to show the consumer demand in the market (Khan et al., 2019). It is an important index to measure the intensity of regional economic activities and the level of residents' consumption. The NKEFAs may affect the regional economic structure and consumption pattern and then affect the upgrading of the industrial structure. By controlling the share of retail sales of consumer goods in GDP, we can eliminate the interference caused by the change in economic activity and evaluate the direct effect of policy.

In examining the innovation and technology situation of the region, we follow the practice of most scholars and choose the indicator of the number of invention patents (Lin and Lee, 2010). The number of invention patents reflects the regional innovation ability and technological strength and plays a significant role in promoting industrial upgrading. When evaluating NKEFAs, considering the number of invention patents can exclude the additional impact of technological innovation on the upgrading of the industrial structure and ensure the accuracy of the evaluation results.

The number of beds in hospitals and health centres refers to the number of medical institutions such as hospitals, clinics, nursing homes, and other medical institutions that are used to provide bed services. It is an important indicator that reflects the size and capacity of healthcare institutions (Garmon, 2022). The NKEFA policy is accompanied by the strengthening of the ecological environment and people's livelihood. In addition, the number of beds in hospitals and health centres can serve as an indicator of policy efforts aimed at improving public wellbeing. Taking it as a controlled variable helps eliminate the potential impact of the people's livelihood security on the upgrading of the industrial structure so that the evaluation results are more focused on the direct impact of policies on the industrial structure.

The registered unemployed population in the city at the end of the year is the basic data that indicates the high or low number of unemployed people in towns and cities (Ono, 2019). The supply and demand situation of the labour market is an important factor affecting the upgrading of the industrial structure. The registered unemployed population reflects the tightness of the regional labour market and has an indirect impact on the upgrading of the industrial structure. By controlling this variable, the potential interference of labour market changes on the industrial structure upgrading can be eliminated, and the evaluation results can be more objective.

A higher number of tertiary education institutions implies that the city has greater competitiveness and attractiveness in the field of education. This not only promotes the development of education in the city but also provides intellectual support (Lee and van, 2019). Colleges and universities are important bases for cultivating high-quality talents, which have a profound influence on the upgrading of the industrial structure. The NKEFAs may promote the upgrading of the industrial structure by improving the educational environment and attracting outstanding talents. Taking the number of institutions of higher learning as a controlled variable is helpful to exclude the additional impact of education level on the upgrading of the industrial structure and evaluate the effect of the policy more accurately.

These variables cover many aspects, such as economic vitality, technological innovation, social security, labour market, education, and talent supply, and can help comprehensively and accurately evaluate policy effects. Table 1 presents descriptive statistics of variables.

5 Empirical results

5.1 Parallel trend test

The parallel trend test is able to assess whether there will be some type of correlation between two sets of variable data with the same magnitude of increase or decrease. The use of the parallel trend test allows for a visual analysis of time trends and confidence intervals. The following shows the results of the parallel trend test for the AIS and the RIS, respectively. This is a necessary prerequisite for the DID model.

Figure 1 is sufficient to show that before the implementation of the pilot policy of the NKEFAs, the development trend of the AIS of the cities in the region converged. However, after the implementation of the policy, the level of AIS of the cities involved shows an upward trend. This result not only shows that the parallel trend test is passed but also indicates that the policy started to play a role in promoting the AIS in the year after implementation. Moreover, the impact of the policy is persistent and beneficial for 3 years thereafter.

Figure 2 indicates that the experimental and control groups do not pass the parallel trend test in terms of RIS. This means that there are some differences between the policy pilot cities and other cities in their original development. In the case of the RIS, the impact of the policy is not obvious.

5.2 Basic regression

The following Table 2 shows the results of the base regression. The results show the AIS and RIS, respectively. It can be seen that the NKEFAs will significantly increase the level of AIS. However, for the RIS, the policy effect is not confirmed as it does not pass the parallel trend test. Therefore, although the regression is significant, this does not represent the net effect of the policy. We believe it is highly likely that there are other factors affecting the movement of the RIS rather than the policy. We emphasise here that since this paper focuses on

TABLE 1 Descriptive statistics.

Variable	N	Minimum	Maximum	Mean	Standard deviation
Retail sales of consumer goods as a share of GDP	1,105	0.1	0.67	0.3465	0.10
Number of patents for inventions	1,105	900	55,331	14,739.78	8,858.81
Number of beds in hospitals and health centres	1,105	1	1,661	110.15	206.46
Registered urban unemployed at the end of the year	1,105	1,297	514,028	19,798.96	26,990.08
Number of higher education institutions	1,105	0	17	3.31	2.83
Investment in education (RMB million)	1,105	10,751	1,850,600	401,210.99	280,117.72
Population density/square kilometre	1,105	5.11	1,269.44	381.90	289.71
AIS	1,105	1.53	2.99	2.21	0.13
RIS	1,105	−0.17	3.14	0.90	0.58
DID	1,105	0	1	0.28	0.45

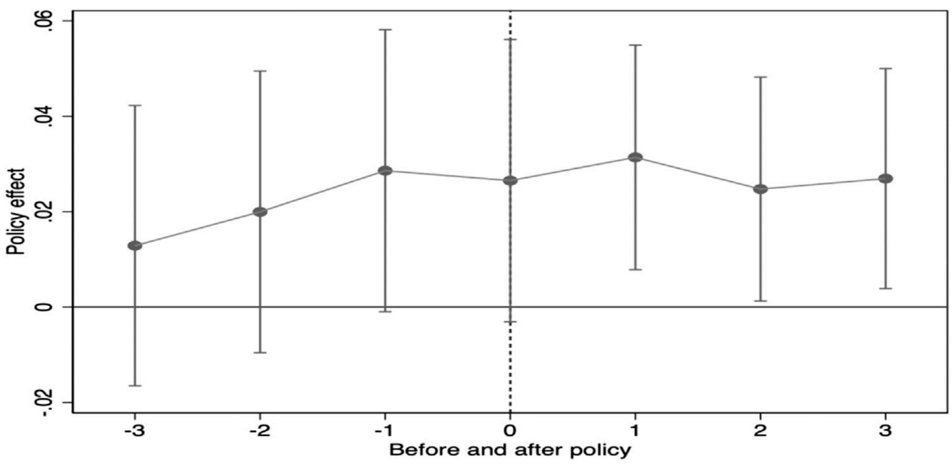

FIGURE 1
Parallel trend test results for advanced industrial structure.

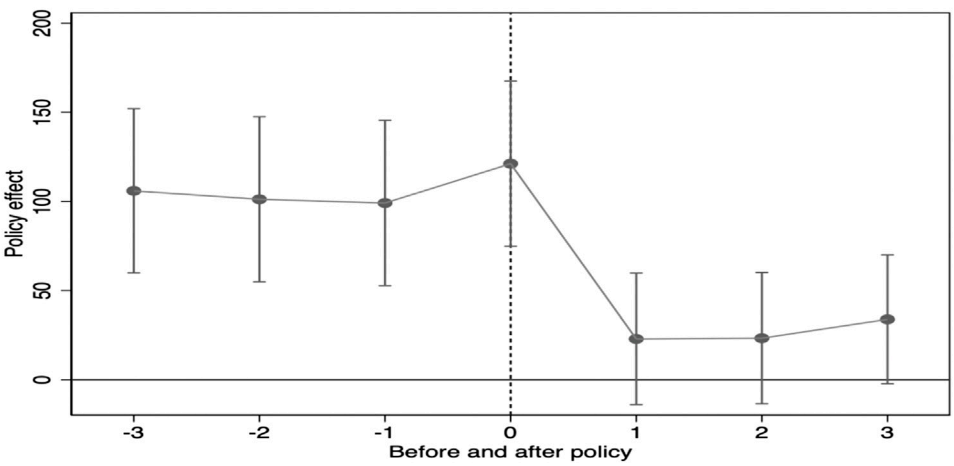

FIGURE 2
Parallel trend test results for the rationalisation of the industrial structure.

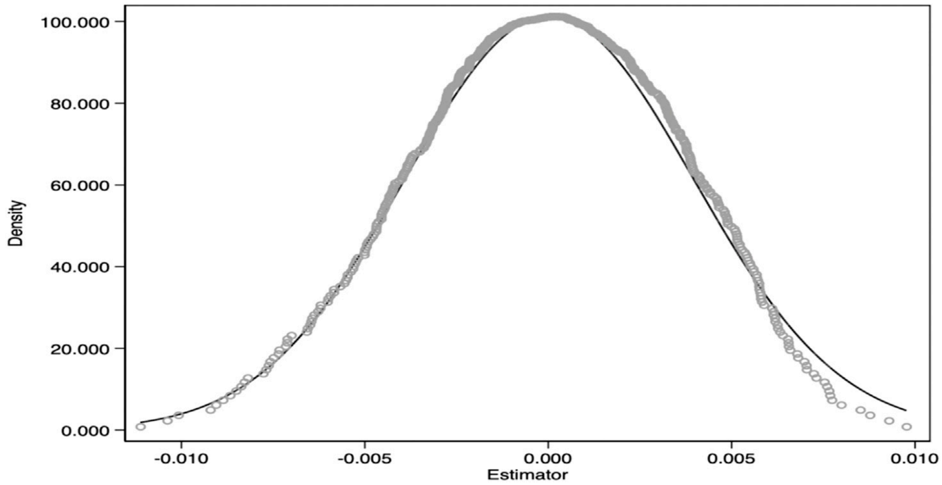

FIGURE 3
Placebo test results.

TABLE 2 Regression results.

Variable	AIS	AIS	RIS	RIS
DID	0.1086*** (12.74)	0.0175* (2.56)	43.4259*** (4.09)	40.4962*** (3.74)
Retail sales of consumer goods as a share of GDP		0.3032*** (6.40)		−95.3108 (−1.27)
Number of patents for inventions		0.0001*** (5.07)		0.0244 (1.08)
Number of beds in hospitals and health centres		0.0000* (2.46)		−0.0030** (−2.82)
Registered urban unemployed at the end of the year		0.0000*** (3.78)		0.0000 (0.23)
Number of higher education institutions		−0.0015 (−0.77)		−1.1379 (−0.37)
Cons	2.1792*** (614.13)	2.0268*** (122.87)	596.6824*** (63.22)	648.5838*** (24.78)
R^2	0.0655	0.6335	0.2275	0.2362
Obs	1,105	1,105	1,105	1,105

Note: t statistics in parentheses; *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

the policy effects of NKEFAs, we will continue to analyse AIS in depth below.

5.3 Robustness tests

5.3.1 Placebo test

In order to avoid the results being affected by unobservable omitted variables, this paper further uses a placebo test to verify the reliability of the benchmark regression. This is done by randomly constructing the experimental group, i.e., randomly assigning prefecture-level cities as pilot sites to carry out the placebo test, and the Figure 3 shows the results of the placebo test for 500 Monte Carlo simulations. The results show that the regression coefficients are mostly distributed around the value of 0, which passes the placebo test.

5.3.2 Deletion of some samples

From the current stage of development, it is an indisputable fact that the Yellow River Basin is economically weak. The policy effect of NKEFAs may be affected by factors such as geographic location, endowment characteristics, environmental carrying capacity, and spatial development pattern, and there may be systematic differences with other cities. Therefore, the samples of cities with faster economic development and better industrial structure in the Yellow River Basin in recent years are excluded.

Dongying is a strategic node bridging the Bohai Sea region and the Yellow River basin, as well as an important petroleum industrial

TABLE 3 Robustness test results.

Variable	Deletion of some samples	Postponed by 1 year	Postponed by 2 years
	(1)	(2)	(3)
DID	0.0163** (2.60)	0.0046 (0.68)	−0.0053 (−0.77)
Cons	2.0240*** (132.39)	2.0301*** (122.62)	2.0327*** (122.89)
R^2	0.6789	0.6313	0.6313
Control	Yes	Yes	Yes
City-FE	Yes	Yes	Yes
Year-FE	Yes	Yes	Yes
Obs	1,027	1,105	1,105

Note: t statistics in parentheses; *p < 0.05, **p < 0.01, and ***p < 0.001.

TABLE 4 Conduction mechanism test results.

Variable	AIS	Investment in education	Population density	AIS
	(1)	(2)	(3)	(4)
DID	0.0175* (2.56)	3.9e+04*** (4.07)	−9.0518** (−3.20)	
Investment in education				0.0000* (2.47)
Population density				0.0002* (2.39)
R^2	0.6335	0.8334	0.1034	
Control	Yes	Yes	Yes	Yes
City-FE	Yes	Yes	Yes	Yes
Year-FE	Yes	Yes	Yes	Yes
Obs	1,105	1,105	1,105	1,105

Note: t statistics in parentheses; *p < 0.05, **p < 0.01, and ***p < 0.001.

base in China. Ordos is designated by the Inner Mongolia Autonomous Region government as one of the provincial sub-centre cities. Yulin is located in Shanxi Province, with the Yellow River to the east and the Shenfu Coal Field, one of the seven largest coal fields in the world. In addition, it has the largest whole gas field proved on land in China—Shanxi Ganning Gas Field. Luoyang is the eastern starting point of the Silk Road and the centre of the Sui and Tang Dynasty Grand Canal. It is not only an important cultural birthplace but also the regional sub-centre of Henan Province. Its GDP ranks high in the country. Weifang is an early industrial city with strong industrial strength and is in a critical period of industrial transformation. Eventually, we keep the other 1,027 samples for re-estimation.

5.3.3 Policy time delay

We postpone the policy implementation time by 1 and 2 years, respectively, as shown in Table 3. And the regression results show that the dummy variable did not have an impact on industrial structure upgrading. This suggests that the results of the study are robust and credible.

5.4 Results of mediating mechanisms

The results in column (2) of Table 4 show that there is a significant positive impact of the pilot policies on education input, i.e., the NKEFAs are actively exploring a new model of promoting innovative development through education (Thompson, 2018). In practice, governments will support and tilt the pilot demonstration areas in terms of policies and funds to promote the development of education. This is conducive to basic theoretical research and talent cultivation for ecological function protection and restoration in key ecological function areas. The coefficients of the mediating variables in column (4) of Table 4

TABLE 5 Heterogeneity analysis between ethnic and non-ethnic areas.

Variable	Ethnic provinces	Non-ethnic provinces
	(1)	(2)
DID	0.0071 (0.50)	0.0197* (2.56)
cons	2.2057*** (69.81)	1.9929*** (98.27)
R^2	0.5566	0.6463
Control	Yes	Yes
City-FE	Yes	Yes
Year-FE	Yes	Yes
Obs	156	949

Note: t statistics in parentheses; $*p < 0.05$, $**p < 0.01$, and $***p < 0.001$.

indicate that the increase in education investment promotes the AIS.

The results in column (3) of Table 4 show that the pilot policy has a significant negative effect on population density, i.e., the NKEFAs continue to adjust the spatial structure to better adapt to the local natural environment during the construction process. Therefore, the population density decreases. Meanwhile, the coefficients of the mediating variables in column (4) of Table 4 indicate that it promotes the AIS. In addition, it reports that the establishment of NKEFAs further expands the impact of population density reduction on AIS.

5.5 Heterogeneity results

5.5.1 Heterogeneity results between ethnic and non-ethnic areas

The eight ethnic provinces refer to the five autonomous regions, namely, Inner Mongolia, Guangxi, Tibet, Ningxia, and Xinjiang, and the three provinces, namely, Guizhou, Yunnan, and Qinghai, where the population of ethnic minorities is relatively concentrated. Given that China is a multi-ethnic country, considering ethnicity is imperative for achieving balanced development. The regression results are shown in Table 5. We found that the policy has no significant effect on the AIS in ethnic provinces, but it has a significant positive impact in non-ethnic provinces.

5.5.2 Heterogeneity results between different city scales

The industrial agglomeration effect depends on whether the city infrastructure is perfect, whether the factor input is abundant, and so on. There are obvious differences in the level of services provided by cities of different scales for industrial agglomeration, which in turn affects the upgrading of the industrial structure. The results of the regression are shown in Table 6. It can be found that in small- and medium-sized cities, the policy did not contribute to the AIS, while the policy in large cities increased the growth of industrial structure upgrading.

6 Discussion

Through the aforementioned results, it is evident that NKEFAs exert a certain impact on the upgrading of the industrial structure. However, discussions on the relationship between environmental policies and industrial structure have been insufficient. To address this gap, we supplement the existing studies based on the test of 85 cities in the Yellow River Basin (Du et al., 2021; Zhang et al., 2019). Furthermore, we can also find that the environmental policy contributes significantly to the AIS but not to the RIS (Zheng et al., 2020). Therefore, the formulation of environmental policies needs to focus more on this issue.

The underlying reasons for this phenomenon can be attributed to several factors. First, in policy areas, the industrial base is generally weak, the people are living in poverty, and it may be difficult to achieve comprehensive optimisation of the industrial structure in the short term by relying solely on policy support. Second, under the pressure of strict ecological environment assessment, some counties may pay too much attention to ecological protection and limit the development of industries,

TABLE 6 Distinguishing analysis between city scale.

Variable	Small- and medium-sized cities	Large cities ≥ 1 billion
	(1)	(2)
DID	0.0070 (0.94)	0.0532** (2.65)
Cons	2.0146*** (119.69)	2.0931*** (40.20)
R^2	0.6433	0.6208
Control	Yes	Yes
City-FE	Yes	Yes
Year-FE	Yes	Yes
Obs	884	221

Note: t statistics in parentheses; $*p < 0.05$, $**p < 0.01$, and $***p < 0.001$.

which affects the rationalisation process of the industrial structure to a certain extent.

Concerning the intermediary mechanism, positive effects are observed in education input and population density. The policy intentionally curtails development space to allocate more area for environmental protection, leading to a reduction in population density. This reduction influences the transformation and upgrading of the industrial structure. Simultaneously, human resources become relatively constrained within the limited development space, necessitating the fulfilment of actual demand through scientific and technological innovation and efficient resource utilisation. However, some studies present contrary findings, suggesting that as population density decreases, human resources may become scarce, hindering industrial structure upgrading (Liu et al., 2019; Chen et al., 2021). The research in this paper explains a new path. Additionally, the positive impact of education investment on industrial structure upgrading passes the significance test. The transmission path through which education enhances industrial structure development by elevating the quality of human capital has been confirmed (Ramos et al., 2012).

In our heterogeneity analysis, we make a crucial distinction between ethnic and non-ethnic provinces—an innovative perspective that has not received much attention previously. Our studies have shown that the policy has no significant impact on AIS in ethnic provinces but has a significant positive impact on non-ethnic provinces.

This outcome can be discussed in depth from the following aspects. First, there are inherent differences between ethnic and non-ethnic provinces on the basis of industry. Non-ethnic provinces usually have a relatively complete industrial system and a strong industrial base and can better undertake the promotion of the NKEFAs and achieve industrial upgrading. However, due to their remote geographical location, inconvenient transportation, weak infrastructure, and other factors, the industrial development of ethnic provinces is relatively lagging, lacking sufficient industrial support and technology accumulation. As a result, it is difficult to achieve industrial upgrading in a short time. Second, there may be some problems with the adaptability of the NKEFAs in ethnic provinces. Due to the unique natural environment, social culture, and economic conditions of ethnic provinces, it may be difficult to fully adapt to these characteristics in the implementation process, resulting in limited policy effects. For example, ethnic provinces may pay more attention to the protection and inheritance of traditional industries, while policies may encourage the development of emerging and high-tech industries, and there are certain conflicts and contradictions between the two. Third, the state of ecological restoration and environmental protection is directly related to the overall ecological security of our country. In ethnic provinces, ecological protection is often placed in a more important position. In the implementation process of the NKEFAs in the ethnic provinces, more attention may be paid to the balance between ecological protection and industrial development to avoid the damage of excessive development to the ecological environment. This has limited the process of industrial upgrading to a certain extent, but it has also laid the foundation for sustainable development.

Regarding the impact of city scale on policy effectiveness, our findings reveal that large cities are conducive to industrial structural upgrading. However, the coefficient for small- and medium-sized cities is not statistically significant.

This is mainly due to the differences in resource allocation, innovation ability, institutional environment, and other factors. First, big cities usually have richer resources, including capital, talent, and technology, and have greater potential in terms of upgrading their industrial structure. So, more policy resources are being directed to these cities (Dai et al., 2022). Second, big cities have more scientific research institutions, universities, and innovative enterprises, which are important driving forces for technological innovation and industrial upgrading. Small- and medium-sized cities may be relatively weak in terms of innovation capacity, so it is difficult to achieve industrial upgrading in the short term. Third, the institutional environment in big cities is usually more complete, including property rights protection, market supervision, and public services. These institutional factors provide better guarantees and support for industrial upgrading. The institutional environment of small- and medium-sized cities may need to be improved, so it is difficult to give full play to the policy effect.

7 Conclusion and policy implications

Through the empirical study, we reveal the complex effects of the construction of NKEFAs in promoting the upgrading of the industrial structure in the Yellow River Basin. The research results show that the policy has a positive impact on promoting AIS but has a limited impact on the RIS. At the same time, investment in education and population density, as an intermediary mechanism, plays an important role in promoting the AIS. In addition, heterogeneity analysis further reveals the differences in policy effects in different provinces and cities. Based on these findings, we propose the following policy recommendations to optimise the construction of NKEFAs in order to more effectively promote the upgrading of the industrial structure in the Yellow River Basin.

First, it is essential to strengthen policy targets and implement differentiation strategies. On one hand, considering the significant role of the construction of NKEFAs in non-ethnic provinces and big cities to promote industrial upgrading, it is suggested that policymakers should focus more resources on these areas and accelerate their industrial structure to a higher level by increasing financial support, optimising industrial layout, and other measures. On the other hand, for ethnic provinces and small- and medium-sized cities, where the policy effect is not significant, it is necessary to explore the path to industrial upgrading in line with local characteristics. For example, by tapping into national cultural resources, developing characteristic industries, etc., these areas can achieve differentiated development while strengthening the coordination between ecological protection and economic development.

Second, it is important to optimise the investment in education and improve the quality of human capital. In view of the positive role of educational investment in promoting the upgrading of the industrial structure, it is suggested that the government further increase investment in education, especially in the less developed areas of the Yellow River basin. This can be achieved by improving the quality of education and expanding the coverage of education resources to provide strong talent support for industrial upgrading. At the same time, combined with the needs of industrial structure upgrading, it is essential to vigorously develop vocational education and skills training and improve the professional skills and innovation ability of the labour force in order to meet the development needs of emerging industries.

Third, it is essential to rationally regulate population density and promote the coordinated development of ecology and industry. While ensuring ecological security, through scientific and reasonable urban planning, the population should be guided to flow in a direction conducive to industrial development and ecological protection so as to avoid ecological pressure caused by excessive concentration. In addition, for areas with high population density and high ecological pressure, policies can guide the flow of population to other suitable areas while promoting the transfer of labour force to emerging and green industries so as to achieve a harmonious coexistence of population, economy, and ecology.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author.

Author contributions

YZ: Writing–original draft, Methodology, Investigation, Formal Analysis, Data curation, Conceptualization, Validation, Writing–review and editing. HL: Methodology, Software, Resources, Funding acquisition, Writing–original draft, Writing–review and editing. CS: Formal Analysis, Validation, Software, Resources, Writing–original draft, Writing–review and editing. YL: Formal Analysis, Methodology, Funding acquisition, Supervision, Writing–review and editing. CX: Project administration, Supervision, Writing–original draft. HW: software, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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