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Research on the impact of FDI and environmental regulation on the industrial structure upgrading in the Yellow River Basin

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Introductions: Since the reform and opening up, the inflow of foreign direct investment (FDI) has provided a steady stream of capital, technology, talent and other resources for the development of the Yellow River basin, while caused problems such as environmental pollution, ecological fragility and industrial structure upgrading difficulties to some extent. Environmental regulation is a pivotal initiative to achieve mutual harmony between ecological environment and economic development, which could enhance the quality of the introduction of FDI and accelerate the green transformation of the development mode.

Methods: Based on urban panel data from 2006–2019, this study empirically examined the impact of FDI and environmental regulation on industrial structure upgrading in the Yellow River Basin. Moreover, taking environmental regulation as a threshold variable, a panel threshold model was established to further explore the role of environmental regulation in the impact of FDI on industrial structure upgrading in the Yellow River Basin.

Results: (1) The relationship between FDI and industrial structure upgrading in the Yellow River Basin is not a simple linear relationship, but an inverted "U"-shaped relationship that rises first and then falls, and the results of this inverted "U"-shaped relationship are still robust after replacing key indicators. (2) The environmental regulation policy has a driving effect on the upgrading of industrial structure in the Yellow River Basin. (3) Environmental regulation has a positive role in the influence of FDI on the industrial structure upgrading in the Yellow River basin, and the positive role increases gradually as the intensity of environmental regulation increases moderately, but if the intensity of environmental regulation is too high, it will have a negative impact on the upgrading of industrial structure in the Yellow River basin to some extent.

Discussion: In the future, policymakers should make reasonable and effective use of FDI and improve the quality of FDI; reasonably formulate environmental regulation policies; coordinate the intensity of FDI and environmental regulation; thus, bring into play the promotion effect of FDI and environmental regulation on industrial structure upgrading, and then realize the win-win of ecological protection and high-quality economic development in the Yellow River Basin.

KEYWORDS

FDI, environmental regulation, industrial structure upgrading, Yellow River Basin, empirical analysis

1 Introduction

As the mother river of the Chinese nation, the Yellow River is an important ecological barrier and economic zone in China. Since the reform and opening up, foreign direct investment (FDI) has become an important force for the economic development of the Yellow River basin, where the amount of foreign capital actually used maintains an upward trend as a whole since 2009 and it tends to be stabilized at ¥290 billion in recent years. FDI has provided a steady stream of capital, technology, talent and other resources for the development of the Yellow River basin, which could not only promote the scientific and technological innovation capacity, but also boost the high-quality economic development (Feng et al., 2019; Wang and Liu, 2019; Zhang, 2021).

However, FDI also has the potential to lead to serious environmental issues (Yu et al., 2021). A considerable amount of FDI has been concentrated in the "high energy consumption, high pollution, low output" of the secondary industry, resulting in environmental pollution, ecological fragility and industrial structure upgrading difficulties, which has become a crucial factor limiting the quality of economic development of the Yellow River Basin. Precisely because of this, on 18 September 2019, President Xi Jinping chaired and addressed a symposium in Zhengzhou, stressing that the protection of the Yellow River is critical to the great rejuvenation and sustainable development of the Chinese nation, and ecological conservation and high-quality development of the Yellow River Basin is a major national strategy.

Not only that, on 8 October 2021, the Communist Party of China Central Committee and the State Council have jointly issued an outline document on the ecological protection and high-quality development of the Yellow River basin, which requires the cities along the Yellow River to plan the development of industries and others based on their water resource capacities. Immediately following, on October 22, President Xi Jinping pointed out that provinces and regions along the Yellow River should implement the strategic plan for the high-quality development, and unswervingly follow the modernization path of ecological priority and green development.

Environmental regulation involves the government's oversight and control of the actions of enterprises and individuals in relation to environmental conservation and resource management, and its implementation depend on the enforcement of laws, policies, and standards (Feng et al., 2024). It needs to be emphasized that environmental regulation is an essential measure for the government to realize mutual coordination between ecological environment and economic development.

In particular, environmental regulation can attract "new entrants" to join the green technology market and launch more green innovations (Yan et al., 2024), which could enhance the quality of the introduction of FDI and accelerate the green transformation of the development mode. Moreover, it has been suggested that the technology spillover effect of FDI is significant under the constraint of environmental regulation (Zou and Chen, 2022).

Hence, when studies refer to FDI and industrial structure upgrading of the Yellow River Basin, it is essential to take the environmental regulation into account. In this case, it is significant to deal with the inherent relationship between FDI, environmental regulation and industrial structure upgrading to fulfill ecological protection and high-quality economic development in the Yellow River Basin. Specifically, the detailed tasks of this study are: (a) respectively search for the relationship between FDI/environmental regulation and industrial structure upgrading in the Yellow River Basin; (b) explore the role of environmental regulation in the impact of FDI on industrial structure upgrading in the Yellow River Basin in depth.

The rest of the paper is organized as follows (as shown in Figure 1). The second section reviews the literature relevant to this study. The theoretical analysis and research hypotheses are presented in the third section. The fourth section describes the variables, data sources, and models. The fifth part is the empirical analysis of this paper, including benchmark regression analysis, heterogeneity analysis, robustness test, and threshold effect test. The sixth, seventh and eighth parts give the research conclusions, countermeasure suggestions and research prospects, respectively.

2 Literature review

In recent years, studies on the impact of FDI on the industrial structure upgrading have been conducted widely. With respect to those researches, the mainstream views of the impact of FDI could be broadly divided into two types: the "pollution haven" hypothesis and the "pollution halo" hypothesis (Feng et al., 2019). On one hand, a vast majority of scholars believe that the inflow of foreign capital can ameliorate the rationalization of industrial structure by providing capital, technology spillover and promoting the flow of production factors, which in turn promotes the upgrading of industrial structure in the host country. Tang et al. (2019) concluded empirically that FDI spillovers have a positive effect on local technological upgrading in nearby and neighboring cities. Yu and Han (2019) conducted an empirical analysis based on VAR model and the results showed the positive impact of foreign direct investment on industrial structure upgrading in Jiangsu province. Wang et al. (2020) introduced spatial autocorrelation analysis method and spatial panel econometric model by constructing a weight matrix of economic distance to prove that FDI is a key driving factor for industrial structure upgrading in China. Wu and Liu. (2021) used the spatial Durbin model to indicate that FDI has positive direct and indirect effects on industrial structure upgrading. Xu (2021) found that the industrial competition brought by FDI has a positive impact on the upgrading and progress of China's industrial structure.

On the other hand, a few scholars argue that the inflow of foreign capital will introduce high pollution and high emission industries. This may make the host country enterprises too dependent on foreign capital instead of pursuing high value-added industries, which is detrimental to the technological research and development of local enterprises and thus hinders the upgrading of the industrial structure of the host country. Li et al. (2021) adopted exploratory spatial data analysis methods to prove the conclusion that FDI can enhance the rationalization of industrial structure, however, to a certain extent, it hampers the upgrading of industrial structure.

The relationship between environmental regulation and industrial structure upgrading is currently viewed as facilitation, inhibition and indeterminacy in academic circles. Wu et al. (2019) took Chinese provincial manufacturing industries as the survey object and found that environmental regulations have

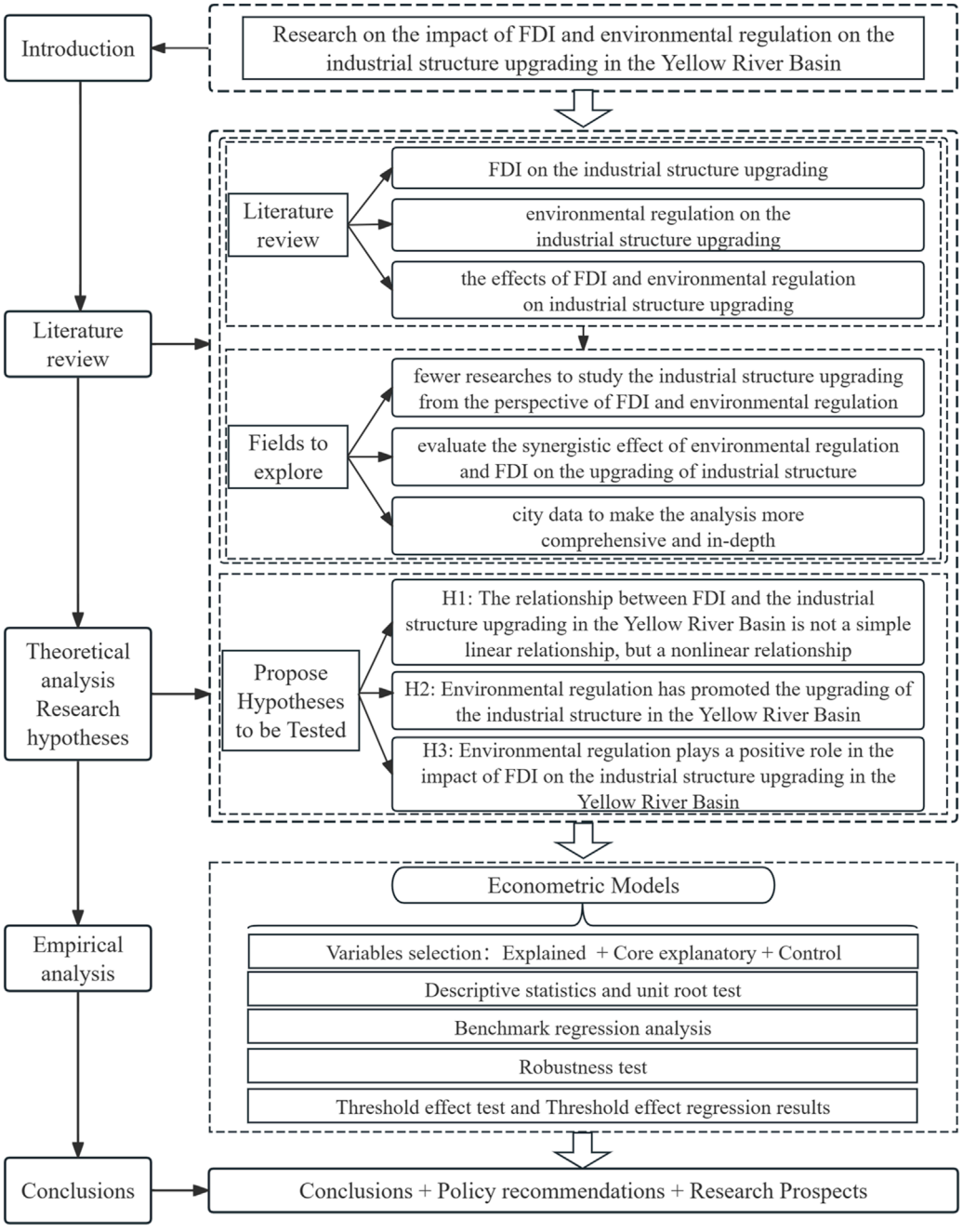

FIGURE 1
Research framework.

a suppressive effect on the industrial structure upgrading of China's manufacturing industry. Chen and Qian (2020) pointed out that adjusting the environmental regulation policy is effective facilitator in enhancing industrial structure upgrading, which in turn promotes the high-quality development of the regional economy. Chen et al. (2020) proved that various types of marine environmental regulations have a positive *U*-shaped relationship with the transfer of polluting industries and industrial structure upgrading. Wang et al. (2020) noted that formal environmental regulations have an inverted "U" shaped direct impact on industrial upgrading and a positive impact on industrial upgrading through technological innovation strategies. Song et al. (2021) held the view that there are regional differences in the impact of environmental regulation on industrial structure upgrading. Under the western sample, there is a negative relationship between environmental regulation and industrial structure upgrading while there is a positive relationship under the national sample and the eastern sample. Zhou et al. (2021) based on a spatial econometric approach to demonstrate that the stringency of environmental regulation helps to optimize the industrial structure. By exploring three

major economic zones in China, Guan et al. (2022b) believed that environmental regulation has a dampening effect on industrial structure rationalization, but effectively promotes industrial structure upgrading. Wang et al. (2022b) argued that command-based environmental regulation and market-based environmental regulation can motivate firms to engage in green technology innovation, which is an efficient technique to promote green economic development. Yin et al. (2022b) used the mediating effects and threshold models, and reported that industrial upgrading in the central and western regions is impeded by environmental regulations.

Some scholars have also started to study the effects of FDI and environmental regulation on industrial structure upgrading. Qiu et al. (2021) asserted that strict environmental regulatory policies can effectively raise the entry barrier of FDI into China, improve the quality of FDI, and enhance the technological absorption capacity of enterprises. Wang et al. (2022a) found that there is a partial mediating effect of FDI in the process of various types of environmental regulations affecting industrial upgrading. Xie et al. (2021) concluded that there is a single threshold of FDI between environmental regulation and industrial structural upgrading by testing the threshold effect. Feng and Liang (2022) found that the moderating effect of environmental regulation is partially and conditionally established. However, Yin et al. (2022a) studied 30 Chinese provinces and argued that environmental regulations impede the spillover and capital accumulation effects of FDI, and curb technological progress to some extent.

Through literature combing, the existing studies provide insights into the role of FDI and environmental regulation in industrial structure upgrading. Both FDI and environmental regulation will have an impact on the upgrading of industrial structure, but unconditional openness and non-strict environmental regulation will have a negative direct effect on economic development (Feng et al., 2019; Zhang et al., 2022). Nevertheless, there are still some fields to explore. Firstly, it is found that there are fewer researches to study the industrial structure upgrading from the perspective of FDI and environmental regulation at the same time, and the literature that takes the Yellow River Basin as the study area is even scarcer. Secondly, this study made the initial effort to evaluate the synergistic effect of environmental regulation and FDI on the upgrading of industrial structure, which bridges the gap between theory and practice by providing a profound vision of spatial econometrics. Finally, this study utilized a panel data of the Yellow River Basin from 2006–2019 rather than provincial data, which makes the analysis more comprehensive and thorough.

Therefore, this study focused on the Yellow River Basin, examined the impact on industrial structure upgrading from the perspective of FDI and environmental regulation, and added the interaction between the two to explore the role of environmental regulation in the impact of FDI on industrial structure upgrading. The panel threshold model was further established to analyze the impact of FDI on the industrial structure upgrading in the Yellow River Basin under different environmental regulatory intensities. This would provide a reference for the coordination and cooperation of FDI and environmental regulation in the Yellow River Basin to promote the industrial structure upgrading.

3 Theoretical analysis and research hypotheses

3.1 FDI and industrial structure upgrading

FDI is an external force for upgrading industrial structure (Cheng et al., 2022). The introduction of FDI in the Yellow River Basin has played a momentous role in its economic development and has become an essential driving force for the industrial structure upgrading in the Yellow River Basin (Water Resources Department of Henan Province, 2021). On one hand, the introduction of foreign capital could provide enterprises with advanced technology and management experience, reduce the production cost of enterprises, boost their production efficiency, and promote the transformation of industries from low value-added to high value-added, which indirectly promotes the industrial structure upgrading of the Yellow River Basin, and form the "pollution halo" (Feng et al., 2019; Zou and Chen, 2022). However, the technology spillover of FDI will also be restricted by domestic technological level, innovation capability and human resources, which may affect the effect of FDI (Feng et al., 2019). On the other hand, the scale of FDI flowing into the tertiary industry in the Yellow River Basin has gradually multiplied, providing financial support for the development of the tertiary industry in the Yellow River Basin (Zhang, 2021), but the entry threshold for the tertiary industry is relatively high, which may affect the pulling role of the FDI in the third industry of the Yellow River Basin.

However, the introduction of FDI also has some negative effects. The excessive introduction of FDI may make the Yellow River Basin enterprises over-reliant on foreign capital, while ignoring the amelioration of their own innovation capabilities and production efficiency. At the same time, it is also possible to introduce some low-quality FDI, such as polluting FDI, which not only causes environmental pollution, but also hinders the economic development, and form the "pollution haven" (Feng et al., 2019). Therefore, the following hypothesis one was put forward.

Hypothesis 1: The relationship between FDI and the industrial structure upgrading in the Yellow River Basin is not a simple linear relationship, but a nonlinear relationship.

3.2 Environmental regulation and industrial structure upgrading

With the gradual aggravation of environmental pollution problems, environmental regulation is of great significance in improving the quality of ecological environment. Environmental regulation can force and guide enterprises to consider environmental factors in their investment and emissions trading, promote the transformation of enterprises from high energy consumption and pollution to low-carbon environmental protection, accelerate the transformation and upgrading of industrial structure (Feng et al., 2024). In addition, with the implementation of environmental regulation policies, the living environment has been greatly ameliorated, the public's awareness of environmental protection is gradually increased, and the public's demand for "green products" is also gradually on the rise, so that enterprises can produce a wider variety of green products to meet

consumer demand, thus promoting industrial restructuring (Chen and Qian, 2020; Liao and Shi, 2018; Du et al., 2021).

With the implementation of China's environmental regulation policies and the popularization of environmental protection concepts in recent years, this study believes that, environmental regulation has promoted the industrial structure upgrading in the Yellow River Basin as a whole, so hypothesis two was proposed.

Hypothesis 2: Environmental regulation has promoted the upgrading of the industrial structure in the Yellow River Basin.

3.3 FDI, environmental regulation and industrial structure upgrading

Since FDI affects the industrial structure of the Yellow River Basin, it also causes environmental pollution, so the implementation of environmental regulation policies can enhance the entry threshold of FDI, refine the quality of FDI, and reduce the introduction of polluting FDI. Most of the synergistic effects of environmental regulation and FDI on urban innovation are significantly positive, implying that the "Porter hypothesis" is established in China when the inflow of FDI cooperated with the implementation of environmental regulation properly (Feng et al., 2019). Environmental regulation can crowd out investment in polluting technology innovation, allow FDI to flow into the technology innovation market, incentivize potential entrants who have identified the green technology market opportunity, and thus promote the upgrading of industrial structure (Yan et al., 2024).

At the same time, the augmentation in environmental regulation costs will also make some foreign-invested enterprises with serious pollution turn to industries with lower environmental regulation intensity, while the tertiary industry has relatively low environmental regulation costs due to its low energy consumption and less pollution. Therefore, it is speculated that environmental regulation has promoted the role of FDI in industrial structure upgrading of the Yellow River Basin to a certain extent. Based on this, hypothesis three was formulated.

Hypothesis 3: Environmental regulation plays a positive role in the impact of FDI on the industrial structure upgrading in the Yellow River Basin.

4 Research design

4.1 Variables selection

4.1.1 Explained variable

Industrial structure upgrading (U) was introduced to denote the explained variable. Referring to the method proposed by Du et al. (2021), this study measured the industrial structure upgrading from the perspective of industrial structure advancement, and conducted theoretical as well as empirical research on this basis. The ratio of the added value of the tertiary industry to the secondary industry was adopted to measure the industrial structure advancement.

4.1.2 Core explanatory variables

In this study, FDI and environmental regulation were selected as the core explanatory variables. Based on the research thoughts of Shi et al. (2022), FDI was expressed by the ratio of the actual use of FDI in each city to the GDP of the year, and adjusted by the average annual exchange rate of the year. Environmental regulation means that the government regulates and manages the behavior of enterprises and individuals through laws, policies, and standards, so to achieve the goal of coordinated development of environment and economy (Feng et al., 2024).

Since the intensity of environmental regulation could not be directly obtained and is limited by data availability in the Yellow River Basin, this study drew on the practice of Meng and Shao. (2020), selected the emission data of industrial sulfur dioxide, industrial wastewater and industrial smoke (powder) dust to construct a comprehensive index of environmental pollution, and utilized its reciprocal to measure the degree of environmental regulation, expressed as ER, which is shown in the formula Eq. 1:

$$ER_{jt} = \frac{1}{E_{jt}} = \frac{1}{\left(\sum_{i=1}^{3} X_{i,jt}/y_{jt}\right)/3} \tag{1}$$

which $X_{i,jt}$ represents the ratio of pollutant discharge amount i in city j in year t to the total emission amount of pollutant i in the country in year t, and y_{jt} represents the ratio of the total industrial output value of city j in year t to the total industrial output value of the country in year t. E_{jt} is the comprehensive index of environmental pollution in city j in year t, The smaller the value, the stronger the intensity of environmental regulation; the larger the value, the weaker the intensity of environmental regulation.

4.1.3 Control variables

In this study, economic development level (EDL), degree of government intervention (GI), higher education level (HEL) and marketization level (ML) were chosen as the control variables. The economy is a critical driving force for the industrial structure upgrading. Referring to the practice of Guan et al. (2022a), this study selected the *per capita* GDP of the cities in the Yellow River Basin to represent the economic development level.

Moreover, the government could promote the industrial transformation and upgrading through financial and policy means. However, improper government control may also bring pressure to enterprises, restrict the market function to allocate resources, and is not conducive to the optimization and upgrading of the industrial structure. Therefore, drawing on the treatment of variable in Li and Ding. (2018), this study selected the ratio of the government fiscal revenue to the regional GDP of the cities in the Yellow River Basin in the current year to represent the degree of government intervention.

In addition, human capital is a valued factor affecting economic growth and industrial structure upgrading. With reference to the research thoughts of Zhu and Liu. (2020), this study adopted the ratio of the number of students in higher education of various cities in the Yellow River Basin to the resident population in the region to measure the higher education level.

Furthermore, the higher the marketization level, the more efficient the flow of resources, which is more conducive to the industrial structure upgrading. Therefore, referring to the treatment

of variable in Zhang and Qin. (2018), marketization level was expressed as "1-(local fiscal expenditure/GDP)".

4.2 Model design

In order to test the impact of FDI on the industrial structure upgrading and whether environmental regulation would affect the effect of FDI on the industrial structure upgrading in the Yellow River Basin, the interaction term FE was hereby added. At the same time, based on the previous analysis, it can be seen that there may be a nonlinear relationship between FDI and industrial structure upgrading, so the quadratic term of FDI was added to the benchmark regression model. Therefore, the benchmark regression model was established as follows in formula Eq. 2:

$$\ln U_{it} = \beta_0 + \beta_1 \ln FDI_{it} + \beta_2 (\ln FDI_{it})^2 + \beta_3 \ln ER_{it} + \beta_4 FE + \beta_j \sum control_{it} + \varepsilon_{it} \quad (2)$$

among them, i represents each city in the Yellow River Basin, t denotes each year, β_0 is a constant term, ε_{it} represents a random disturbance term, U_{it} is the industrial structure upgrading, ER_{it} denotes the environmental regulation, and $control_{it}$ represents a set of control variables, including the economic development level (EDL), the degree of government intervention (GI), the higher education level (HEL), and the marketization level (ML).

At the same time, in order to further explore the positive influence of environmental regulation on FDI and the industrial structure upgrading in the Yellow River Basin, this study introduced environmental regulation as a threshold variable to construct a following threshold panel model Eq. 3 to clarify its positive impact under different intensities.

$$\begin{aligned} \ln U_{it} = {} & \varphi_0 + \varphi_1 \ln FDI_{it} (\ln ER_{it} \le \gamma) + \varphi_2 \ln FDI_{it} (\ln ER_{it} > \gamma) \\ & + \varphi_3 F^* E(\ln ER_{it} \le \gamma) + \varphi_4 F^* E(\ln ER_{it} \ge \gamma) \\ & + \varphi_j \sum control_{it} + \varepsilon_{it} \end{aligned} \quad (3)$$

which φ_0 is the constant term, γ represents the threshold value of environmental regulation.

4.3 Study area setting and data sources

According to the "Hohhot-Baotou-Erdos-Yulin City Cluster Development Plan," "Guanzhong Plain City Cluster Development Plan," "Central Plain City Cluster Development Plan," "Lanzhou-Xining City Cluster Development Plan" and the city cluster development plans of various provinces and cities, the Yellow River Basin was set as seven city clusters, namely, the Hohhot-Baotou-Erdos-Yulin City Cluster, City Cluster along the Yellow River in Ningxia, and Lanzhou-Xining City Cluster in the upper reaches, Guanzhong Plain City Cluster, Jinzhong City Cluster, and Central Plain City Cluster in the middle reaches, as well as Shandong Peninsula City Cluster in the lower reaches. Among them, as the data of autonomous prefectures in Lanzhou-Xining City Cluster was not available, and Haidong City, Wuzhong City, Zhongwei City, Tianshui City, Dingxi City, Baiyin City, Jiyuan City and Yangling Demonstration Zone have serious data shortages, they were excluded from the study area.

Thus, in this study, 53 cities in the Yellow River Basin were selected. All the data were collected from the "China Statistical Yearbook," "China Urban Construction Statistical Yearbook" and "China Environmental Statistical Yearbook" from 2006 to 2019. Partial missing data were filled by linear interpolation. Specially, the following calculation was conducted based on Stata 16.0 software.

4.4 Descriptive statistics and unit root test

In particular, this study introduced the logarithm of all variables into the model to reduce the heteroscedasticity problem in model setting. Table 1 describes the mean value, standard deviation, minimum value, median value and maximum value of each variable.

In addition, 14 years of data collected by this study belong to the short panel data. However, due to the time-series nature of panel data, nonstationary time series would lead to the phenomenon of "pseudo regression." Therefore, HT test was introduced into this study to test the stationarity of each variable, and the results are shown in Table 2. It can be seen that some variables in the original series failed the stationarity test, but the first-order difference series were all significant at the 1% significance level, which was expressed as a first-order single integer.

5 Empirical analysis

5.1 Benchmark regression analysis

From the Hausman test results (as shown in Table 3), the p-value of 0.0097 is less than the significance level of 0.05, the null hypothesis of the fixed effect model could be accepted. It can be concluded that the fixed effects regression method should be utilized for the panel data in this study. Therefore, the fixed effects model was introduced to empirically analyze the relationship between FDI and the industrial structure upgrading in the Yellow River Basin.

At the same time, this study performed stepwise regression to improve the robustness, and the regression results based on the fixed effects model are shown in Table 4.

It can be seen from models (1) to (7) that the coefficient of FDI primary term is significantly negative. As for FDI quadratic term, the coefficient in model (2) is negative but not significant, while in models (3) to (7), it is significantly negative. The results indicated that the relationship between FDI and the industrial structure upgrading in the Yellow River Basin is not a simple linear relationship, but an inverted "U"-shaped relationship that firstly rises and then falls. That is to say, the proportion of FDI in GDP is not the more the better, but within a suitable range, FDI could promote the industrial structure upgrading in the Yellow River Basin, otherwise it would be counter-productive, which verifies the Hypothesis 1.

In addition, it can be seen from the benchmark regression results (as illustrated in Table 3) that the current FDI in the Yellow River Basin is at the right end of the inverted "U"-shaped curve. In other words, the large proportion of FDI in GDP hampers the industrial

TABLE 1 Descriptive statistics.

Variable	Sample size	Mean value	Standard deviation	Minimum value	Median value	Maximum value
lnU	742	−.3263028	.4425957	−1.671056	−.3194326	.9114966
lnFDI	742	−4.49823	1.219242	−9.211221	−4.326281	−1.08761
lnER	742	.1003504	1.106484	−4.205263	.202896	2.647152
lnEDL	742	10.4947	.6586391	8.476371	10.53562	12.16495
lnGI	742	−2.708564	.3501431	−3.794952	−2.683311	−1.730207
lnHEL	742	−4.379065	1.123383	−7.931242	−4.492064	5.065858
lnML	742	−.1730123	.0945311	−.7792926	−.1504496	−.0435896

TABLE 2 Unit root test results.

lnU	−1.6545**	D_ lnU	−23.5531***
lnFDI	−10.3056***	D_ lnFDI	−34.0437***
lnER	−3.7404***	D_ lnER	−39.2317***
lnEDL	1.5545	D_ lnEDL	−17.6185***
lnGI	−0.2520	D_ lnGI	−25.4698***
lnHEL	−27.0897***	D_ lnHEL	−57.0950***
lnML	−1.8787**	D_ lnML	−30.9874***

D_ means the first-order difference. *,** and *** represent significance at the 10%, 5% and 1% levels, respectively (similarly hereinafter).

TABLE 3 Fixed effects and random effects regression results.

Variable	Fixed effects	Random effects
lnFDI	−.2101937	−.1994592
$(lnFDI)^2$	−.0193382	−.0186776
LnER	.1601582	.1380704
F * E	.0390483	.0339894
lnEDL	.1671074	.1526516
LnGI	.0335328	.0539746
lnHEL	.0503762	.0785607
lnML	−1.869141	−1.785496
constant term	−2.628635	−2.248151
F value	28.83	
Prob>chi2 = 0.0097		

structure upgrading in the Yellow River Basin to a certain extent. The reason may be that the proper introduction of foreign capital, that is, the low proportion of FDI in GDP, could reduce the production cost of enterprises, encourage them to carry out technological innovation, and promote the industrial structure upgrading in the Yellow River Basin. However, the introduction of foreign capital may also cause environmental pollution. When attracting more foreign capital and accounting for a large proportion of GDP, not only foreign technology and management experience but also foreign capital of uneven quality is introduced. Poor quality technical experience and human resources hinder the industrial structure upgrading. At the same time, it would also make enterprises overly dependent on foreign capital, ignoring their own productivity and technological innovation, thereby curbing the industrial structure upgrading.

The coefficient of environmental regulation is positive, which is significant at the 5% significance level in models (3) to (6), and 1% significance level in model (7), indicating that environmental regulation has promoted the industrial structure upgrading in the Yellow River Basin. Although this finding is different from the positive "U"-shaped conclusion of the existing studies, it is consistent with the later conclusion that the two are positively related, and to a certain extent verifies the Porter hypothesis. That is, environmental regulation could force enterprises to carry out technological innovation, which in turn could promote the entire industry upgrading, verifies the Hypothesis 2.

The reason may be that in recent years, the environmental regulation policies of the Yellow River Basin have burdened enterprises with more environmental governance costs, and the profit rate has fallen, which forced enterprises to carry out technological innovation. In the end, the compensation brought by enterprises' technological innovation made up for the cost of environmental regulation. The environmental regulation policy of the Yellow River Basin has played a positive role in the industrial structure upgrading.

The coefficient of interaction term (FE) between FDI and environmental regulation is positive and passed the significance test, which shows that environmental regulation could promote the effect of FDI on the industrial structure upgrading of the Yellow River Basin. That is to say, environmental regulation has a positive role in promoting the impact of FDI on the industrial structure upgrading, which verifies the Hypothesis 3.

Among the control variables, the regression coefficient of economic development level is significantly positive, indicating that

TABLE 4 Stepwise regression results of fixed effects model.

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)
LnFDI	−.0394872*** (−2.65)	−.1387748** (−2.23)	−.1838754*** (−2.79)	−.1578243*** (−2.88)	−.1851086*** (−3.35)	−.1817009*** (−3.31)	−.2101937*** (-3.96)
$(lnFDI)^2$	–	−.0095448 (−1.64)	−.0147129** (−3.01)	−.0175865*** (−3.40)	−.0171865*** (−3.34)	−.0193382*** (-3.89)	
LnER	–	–	.1439248** (2.56)	.108464** (2.32)	.1211644** (2.59)	.118883** (2.56)	.1601582*** (3.54)
F*E	–	–	.0347824*** (2.95)	.0345308*** (3.53)	.0366158*** (3.75)	.0355222*** (3.66)	.0390483*** (4.17)
LnEDL	–	–	–	.3414867*** (17.52)	.2922212*** (11.23)	.2628986*** (9.53)	.1671074*** (5.63)
LnGI	–	–	–	–	.1542044*** (2.84)	.1537742*** (2.85)	.0335328 (0.61)
LnHEL	–	–	–	–	–	0641452*** (3.06)	.0503762** (2.48)
LnML	–	–	–	–	–	–	−1.869141*** (−7.27)
_cons	−.5039251*** (−7.44)	−.7432444*** (−4.63)	−.8439151*** (−4.98)	−4.289201*** (−17.73)	−3.433637*** (−8.91)	−2.839443*** (−6.61)	−2.628635*** (−6.33)
R^2	0.0101	0.0140	0.0270	0.3284	0.3362	0.3452	0.3923
N	742	742	742	742	742	742	742

The corresponding t values are in parentheses (similarly hereinafter).

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the economic development in the Yellow River Basin has promoted the industrial structure upgrading, thus proving that the economy is a critical driving force for the industrial structure upgrading. The higher the economic development level, the stronger the promotion effect on the industrial structure upgrading in the Yellow River Basin. In addition, the economic development level reflects people's wealth creation ability, and high wealth creation ability also means people's high consumption level. The higher the consumption level, the better the development of the tertiary industry. Meanwhile, enterprises would also innovate to produce more high value-added products, thereby promoting the industrial structure upgrading in the Yellow River Basin.

The coefficient of degree of government intervention is significantly positive at the significance level of 1% in both models (5) and (6), indicating that government intervention has a positive effect on the industrial structure upgrading in the Yellow River Basin. Moderate government intervention could provide financial support and policy support for the transformation of enterprises, ultimately promoting the industrial structure upgrading in the Yellow River Basin. The regression coefficient of higher education level is significantly positive. In other words, higher education has cultivated high-tech talents, and the human capital delivered to the society has caused the agglomeration of other production factors, which has promoted the technological innovation of enterprises, and has a positive promotion effect on the industrial structure upgrading in the Yellow River Basin. The coefficient of marketization level is significantly negative at the significance level of 1%. The possible reasons are that the government has less intervention in the market and enterprises, and the market self-regulation in the Yellow River Basin is flawed. There may be problems such as improper resources allocation and unequal social distribution, affect the sustainable growth of economy in the Yellow River Basin, which is not conducive to the industrial structure upgrading.

5.2 Robustness test

In order to confirm the robustness of the benchmark regression results, this paper adopts the method of replacing key indicators to conduct robustness test. Referring to the practices of Ji et al. (2022), the industrial structure hierarchy coefficient including the primary industry, the secondary industry and the tertiary industry is used as a measure of the upgrading of the industrial structure. The measurement formula of the new industrial structure upgrading is shown in Eq. 4:

$$U = \sum_{i=1}^{3} x_i \times i \tag{4}$$

which x_i represents the proportion of the output value of the i industry to the total output value; i denotes the corresponding weight assigned to each industry, $i = 1, 2, 3$.

The robustness test results are shown in Table 5. It can be seen that after replacing the key indicators, the coefficients of the primary and secondary terms of FDI are still significantly negative, indicating that the relationship between FDI and the upgrading of the industrial structure in the Yellow River Basin is still the inverted "U"-shaped relationship verified above; other environmental regulation coefficients are significantly positive, which is consistent with the previous research results that environmental regulation has a promoting effect on the upgrading of the industrial structure in the Yellow River Basin; the coefficient of interaction between FDI and environmental regulation is significantly positive, which is consistent with the previous research results; the coefficients of each control variable have changed slightly, However, neither the sign direction nor the significance has changed. It can be seen that the results of the previous empirical analysis are robust.

5.3 Threshold effect test

Table 6 shows the estimated results of the threshold effect test. The F statistic of the single threshold of environmental regulation is 47.68, which is significant at the 1% significance level and passed the single threshold test; the F statistic of the double threshold is 28.68, which passed the 5% significance level test. This shows that there is a double threshold effect of environmental regulation in the impact of FDI on the upgrading of the industrial structure in the Yellow River Basin. The environmental regulation thresholds are 1.7176 and −1.7148, respectively.

From the regression results of the threshold effect in Table 7, it can be seen that the double threshold of environmental regulation divides the intensity of environmental regulation into three ranges: low (lnER≤−1.7148), medium (−1.7148<lnER≤1.1716) and high (lnER> 1.1716). When the intensity of environmental regulation is in the lower intensity range, the regression coefficient of FDI and the regression coefficient of the interaction term of FDI and environmental regulation are all significantly negative, which are −0.1199222 and −0.0243728, respectively; when the intensity of environmental regulation crosses the first threshold, When it is in the medium intensity range, the regression coefficient of the FDI term is not significant, indicating that the inhibitory effect of FDI on industrial structure upgrading is not obvious at this time, and the regression coefficient of the interaction term rises to 0.0233899, which is significant at the level of 1%; When the double threshold is in the higher intensity range, the coefficient of FDI is significantly positive at 0.0851813, while the coefficient of the interaction term is negative. It can be seen that in the process of gradually increasing the intensity of environmental regulation, the FDI regression coefficient changed from negative to positive and gradually increased, indicating that environmental regulation has a positive role in promoting the impact of FDI on the upgrading of the industrial structure in the Yellow River Basin, which further verifies the Hypothesis 3; the interaction term coefficient changes from negative to positive when the intensity of environmental regulation crosses the first threshold, indicating that this positive promoting effect is gradually enhanced, and when the intensity of environmental regulation crosses the second threshold, the interaction term coefficient becomes negative, that is, although under the intensity of environmental regulation, FDI can promote the upgrading of the industrial structure in the Yellow River Basin. However, if the environmental regulation intensity is too high, it may also lead to excessive production costs of enterprises, which in turn has a negative impact on the upgrading of the industrial structure in the Yellow River Basin to a certain extent.

TABLE 5 Robustness test results.

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (6)
LnFDI	−.0187893** (−2.30)	−.0145553*** (−2.61)	−.0172628*** (−3.06)	−.0170766*** (−3.03)	−.0182195*** (−3.24)
$(lnFDI)^2$	−.0014955** (−1.95)	−.0016288*** (−3.10)	−.0018326*** (−3.47)	−.0018107*** (−3.43)	−.001897*** (−3.60)
LnER	.0240493*** (3.45)	.018286*** (3.83)	.0195463*** (4.09)	.0194217*** (4.07)	.0210773*** (4.41)
F * E	.0042369*** (2.90)	.004196*** (4.20)	.0044029*** (4.42)	.0043432*** (4.36)	.0044846*** (4.52)
lnEDL	–	.0555007*** (27.90)	.0506119*** (19.06)	.0490098*** (17.32)	.0451675*** (14.37)
LnGI	–	–	.0153022*** (2.76)	.0152787*** (2.76)	.0104557* (1.81)
lnHEL	–	–	–	.0035047 (1.63)	.0029525 (1.37)
lnML	–	–	–	–	−.0749728*** (−2.75)
_cons	.770281*** (36.66)	.2103301*** (8.52)	.2952305*** (7.50)	.3276959*** (7.44)	.3361515*** (7.65)
R^2	0.0246	0.5438	0.5488	0.5506	0.5555
N	742	742	742	742	742

TABLE 6 Threshold effect test and estimation results.

Threshold variable	Threshold number	F statistic	1% threshold	5% threshold	10% threshold	Estimated threshold
LnER	single threshold	47.68***	49.4336	37.0145	31.8310	1.1716
	double threshold	28.68**	30.8965	27.1047	22.7699	−1.7148
	triple threshold	13.50	73.5477	54.9519	47.8159	1.9258

TABLE 7 Threshold effect regression results.

Environmental regulation range	lnFDI	F * E
lnER≤-1.7148	−.1199222*** (−4.98)	−.0243728** (−2.58)
−1.7148<lnER≤1.1716	−.0030318 (−0.25)	.0233899*** (5.37)
lnER>1.1716	.0851813** (2.06)	−.0704012** (−2.57)
_cons	−2.172846*** (−5.41)	−2.172846*** (−5.41)
control variable	yes	Yes
n	742	742
R^2	0.4455	0.4455

6 Conclusion

The industrial structure upgrading is a prominent prerequisite for achieving high-quality development. To achieve high-quality economic development in the Yellow River Basin, it is necessary to optimize the industrial structure and realize green development. This study selected the panel data of 53 cities in the Yellow River Basin from 2006 to 2019, and empirically analyzed the relationship between FDI, environmental regulation and industrial structure upgrading in the Yellow River Basin, and obtained the following research conclusions.

1) The relationship between FDI and the industrial structure upgrading in the Yellow River Basin is not a simple linear relationship, but an inverted "U"-shaped relationship that firstly rises and then falls. This shows that as the proportion of FDI in GDP gradually enlarges, FDI would firstly promote the industrial structure upgrading in the Yellow River Basin, while it reaches a certain level, FDI would have a negative effect on the industrial structure upgrading. Moreover, the finding of this inverted "U"-shaped relationship is still stable after the replacement of key indicators.
2) Environmental regulation policies have a role in promoting the industrial structure upgrading in the Yellow River Basin, that is, they could force enterprises to carry out technological innovation, raise productivity and profit margins, make up for the cost of sewage and pollution control, and then promote the transformation and upgrading of the entire industry in the Yellow River Basin. To a certain extent, the "Porter Hypothesis" has been verified, and this is in line with the research results of Yan et al. (2024)

3) Environmental regulation has a positive contribution in promoting the impact of FDI on the industrial structure upgrading in the Yellow River Basin, and with the moderate increment in the intensity of environmental regulation, the positive effect is gradually enhanced. However, if the intensity of environmental regulation is too high, it may also result in excessive production costs, which will be detrimental to the industrial structure upgrading in the Yellow River Basin to a certain extent. These are consistent with the findings of Feng and Liang (2022), who figured out that the moderating role of environmental regulation is partially and conditionally established.

To be specific, the environmental regulation thresholds are 1.1716 and −1.7148, respectively. In the process of increasing the intensity of environmental regulation and crossing the value of −1.7148, the negative impact of FDI on the impact coefficient in the Yellow River Basin is constantly weakening. When the first threshold value of 1.1716 is crossed, the coefficient of FDI on the industrial structure upgrading changes from negative to positive. This represents that environmental regulation has a positively facilitating effect on the impact of FDI on the industrial structure upgrading in the Yellow River Basin, which verifies the thesis of Feng et al. (2019) on the synergistic effect of environmental regulation and FDI.

At the same time, with the moderate rise in the intensity of environmental regulation, the positive role also gradually increases. With the gradual strengthening of the intensity of environmental regulation, the cross-term coefficient of FDI and environmental regulation firstly turns from negative to positive, and then from positive to negative, suggesting that if the intensity of environmental regulation is too strong, the interaction between FDI and environmental regulation would restrict the industrial structure upgrading in the Yellow River Basin. This finding further extends the study of Feng et al. (2019), which bridges the gap between theory and practice by providing a profound vision of spatial econometrics.

(4) The economic development level, degree of government intervention and higher education level have a significant role in promoting the industrial structure upgrading, and the marketization level has a negative impact on the industrial structure upgrading in the Yellow River Basin. A higher level of economic development reflects a higher standard of living. With the amelioration of living standards, people's consumption needs are more and more diversified, which is conducive to the transformation and upgrading of enterprises to meet people's diversified consumption needs, thereby promoting the development of the tertiary industry, and this is similar to the research results of Guan et al. (2022b). The government can create a good environment for industrial structure upgrading and provide financial and policy support for the development of enterprises, which is in line with the findings of (Li et al., 2021; Zhang et al., 2022). Therefore, the government's moderate intervention could drive the industrial structure upgrading. Higher education can cultivate high-quality talents with scientific skills and innovation capabilities, and this is consistent with the research results of (Zhu and Liu, 2020; Zhang, 2021). Human capital can spur the aggregation of other capitals, and is also a valued factor affecting the industrial structure upgrading and economic growth. The marketization level has a negative effect on the industrial structure upgrading, which is similar to the findings of Zhang and Qin, (2018). The market in the Yellow River Basin may have problems such as improper allocation of resources and unequal distribution, which affects the development of enterprises and thus stunts the industrial structure upgrading in the Yellow River Basin.

7 Policy recommendations

Based on the above research conclusions, this study put forward the following policy recommendations.

1) Introduce FDI reasonably and effectively to raise the quality of FDI. On one hand, the government should set up a reasonable scale of investment introduction, strengthen the management of FDI introduction, raise the entry threshold of FDI, control the proportion of FDI in GDP, and give full play to the role of FDI in promoting the industrial structure upgrading in the Yellow River Basin. On the other hand, enterprises should give full play to their subjective initiative, bring productivity gains and innovation capacity from their own perspective, avoid over-reliance on FDI, and make full use of the technological spillover effect of FDI to reinforce their own technological innovation capacity. The FDI technology spillover effect should be fully utilized to improve their own technological innovation capabilities.
2) Rationally formulate environmental regulation policies and give full play to the role of environmental regulation in promoting the industrial structure upgrading in the Yellow River Basin. The government should formulate appropriate environmental regulation policies based on regional differences. It should complete the legal system for environmental regulation, constrain the production activities of enterprises, strictly implement supervision and control, increase investment in environmental pollution control, and limit emissions of pollutants such as sulfur dioxide, industrial wastewater and industrial dust.
3) Coordinate the intensity of FDI and environmental regulation, and organically combine the two to promote the industrial structure upgrading in the Yellow River Basin. Strictly implement environmental regulation policies, attract more high-quality, low-emission, and low-pollution FDI industries, maximize the proactive role of environmental regulation between FDI and the industrial structure upgrading in the Yellow River Basin, and realize the win-win for the introduction of high-quality FDI and ecological environmental protection.
4) Create a favorable environment for industrial structure upgrading. The economic development level, degree of government intervention and higher education level all have a significant role in promoting the industrial structure upgrading in the Yellow River Basin. Consequently, the government should promote the industrial structure upgrading by improving the level of economic development, appropriately intervening in the production and operation activities of enterprises, and vigorously cultivating higher

education talents. At the same time, the role of the market should be better brought into play, the rational allocation of resources should be realized, and the inhibitory effect on the industrial structure upgrading should be alleviated.

8 Research prospects

Though the effectiveness of environmental regulation, FDI and its interaction term on the industrial structure upgrading was preliminarily investigated in this study, some limitations remain and in-depth studies are still needed. (1) Industrial structure upgrading includes two aspects: industrial structure advancement and industrial structure rationalization. In this study, industrial structure advancement represents the upgrading of industrial structure, and the content of industrial structure rationalization should be appropriately added in the later stage to further strengthen the persuasive of this study. (2) Concentrated on the whole Yellow River basin, this study explored the impact of environmental regulation and FDI on the upgrading of industrial structure, without considering the regional spatial heterogeneity. (3) Limited by the availability and stability of data, the method of measuring environmental specifications could be further optimized, and a more scientific and effective index system should be built in the future and calculated by comprehensive index method.

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

JY: Writing–original draft, Writing–review and editing.

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Conflict of interest

The author declares 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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