

Essay

Exploring the Impact of Enterprise Entry and Exit on Ecological Environment Performance: Evidence from China's Strategic Emerging Industries

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Abstract

Strategic Emerging Industries (SEIs) are a critical driver of China's green transition and high-quality development; however, the Ecological and Environmental Effects of Firm Entry and Exit remain insufficiently explored. Based on micro-level data of Chinese SEI enterprises from 2009 to 2023, this study employs kernel density estimation and a panel fixed-effects model to construct a five-dimensional ecological environment evaluation system under the PSDRP framework and to examine the spatio-temporal evolution characteristics of Firm Entry and Exit and their Ecological and Environmental Effects. The results indicate that SEI enterprises exhibit agglomeration in the Eastern Region and gradual diffusion toward the Western Region, with exit activities showing higher spatial concentration. Firm Entry generates stage-specific constraining effects on the ecological environment, whereas Firm Exit alleviates ecological Pressure and enhances Resilience. Significant regional heterogeneity is observed, forming a pattern of optimization in the Eastern Region, improvement in the Central and Western Regions, and greater adjustment challenges in the Northeast Region. This study provides empirical evidence for differentiated and coordinated industrial–environmental policy design.

Keywords: Strategic Emerging Industries (SEIs); firm entry and exit; ecological and environmental effects; spatio-temporal evolution characteristics; regional heterogeneity

1. Introduction

Since the launch of reform and opening-up, China's economy has experienced sustained rapid growth; however, resource and environmental constraints have become increasingly binding, and ecological and environmental issues have gradually emerged as critical factors restricting high-quality development. Ecological civilization construction has been elevated to a national strategic priority, and continuous improvement in ecological and environmental quality has become a central objective of development policy. Confronted with the dual challenges of global climate change and the transition toward high-quality economic development, the existing ecological and environmental carrying capacity is insufficient to sustain the persistent degradation and pollution associated with traditional extensive industrial growth models, thereby constraining long-term sustainable development [1]. Although notable progress has been made in ecological governance in recent years, substantial regional disparities remain in terms of pollution pressure, environmental governance capacity, and ecological restoration levels [2]. Therefore, effectively coordinating economic growth with ecological and environmental improvement during



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industrial transformation and upgrading has become an urgent and practical challenge for China.

As a key driver of future economic and social development, Strategic Emerging Industries (SEIs) have been assigned the strategic mission of promoting high-quality economic growth and industrial structure upgrading. Since 2010, a series of national development plans have positioned SEIs as a core force for enhancing China's competitiveness in emerging economic and technological frontiers [3]. Between 2018 and 2023, investment by central state-owned enterprises in SEIs increased from 0.7 trillion yuan to 2.18 trillion yuan, with its share of total investment rising from 12.8% to 35.2%, representing an average annual growth rate of 24.97%. This rapid expansion has substantially accelerated industrial upgrading and the integration of industrial chains. As micro-level agents of economic activity, firms' entry and exit decisions play a fundamental role in shaping regional industrial renewal and economic development trajectories [4].

From an ecological and environmental perspective, Firm Entry and Exit are not merely economic phenomena but processes that influence regional ecosystems through multiple transmission mechanisms. On the one hand, new firm entry may induce resource agglomeration, increased energy consumption, and higher pollution emissions, thereby intensifying ecological Pressure. On the other hand, alongside technological progress and greater investment in green governance, firm entry may facilitate the diffusion of cleaner production technologies and strengthen environmental governance capacity [5]. Similarly, while Firm Exit can reduce pollution emissions and resource consumption, it may also weaken regional Resilience and diminish the endogenous driving force for green industrial transformation. Therefore, the Ecological and Environmental Effects of SEIs' Firm Entry and Exit are inherently multidimensional, and their direction and magnitude depend on the interaction of industrial characteristics, regional development stages, and institutional environments.

Although extensive research has examined the relationship between industrial development and the ecological environment, notable limitations remain in explaining the micro-level Ecological and Environmental Effects of SEIs. First, most studies focus on traditional industries or macro-level restructuring, with limited attention to firm-level dynamics within SEIs. Second, systematic empirical evidence on how Firm Entry and Exit affect multidimensional Ecological and Environmental Effects—particularly regarding their direction and magnitude across different spatio-temporal scales—remains insufficient. Third, few studies explore regional heterogeneity across areas at different development stages. For example, does SEIs' Firm Entry necessarily improve the ecological environment? Does Firm Exit only reduce pollution, or might it also weaken regional Resilience? Do these effects differ across the Eastern Region, Central Region, Western Region, and Northeast Region? These questions require further empirical examination.

In this context, this study focuses on SEIs' Firm Entry and Exit and systematically analyzes their effects on regional Ecological and Environmental Effects. It posits that Firm Entry and Exit of Chinese SEIs exert significant and multidimensional impacts, with pronounced regional heterogeneity. Using micro-level data on Chinese SEIs from 2009 to 2023, this study applies kernel density estimation to characterize spatio-temporal evolution characteristics and constructs a multidimensional ecological environment evaluation system incorporating Pressure, Support, Destructiveness, Resilience, and Promotion (PSDRP). The contributions are twofold. First, from a firm-dynamics perspective, it empirically examines the differentiated effects of SEIs' Firm Entry and Exit on the five ecological forces. Second, from a regional heterogeneity perspective, it identifies spatial disparities across the Eastern Region, Central Region, Western Region, and Northeast Region. The findings enhance understanding of the interaction between industrial renewal and ecological evolution and provide evidence for differentiated regional industrial–environmental policy design.

2. Literature Review

2.1. Measurement of Ecological and Environmental Effects and Their Influencing Factors

Accurate measurement of Ecological and Environmental Effects is fundamental to evaluating changes in ecological quality and policy outcomes. Existing studies generally adopt two approaches. The first relies on single environmental indicators—such as pollutant emissions, PM2.5 concentration, or carbon emission intensity per unit of output—to reflect environmental conditions [6,7]. Although straightforward, these measures fail to capture the multidimensional feedback mechanisms within ecosystems. The second constructs composite indices based on integrated indicator systems (e.g., entropy weight method, PCA, and the PSR framework), incorporating resource consumption, pollution emissions, and governance investment to reflect environmental complexity and dynamic evolution [8,9].

Scholars generally agree that economic development level, industrial structure, technological progress, and institutional environment are key determinants of ecological and environmental quality. Domestic studies primarily examine the relationship between industrial structure and the ecological environment [10–15], the interactive mechanisms between industrial layout and ecological systems [16,17], and the Ecological and Environmental Effects of specific industries, such as tourism and energy [18–20]. These studies generally suggest a co-evolutionary relationship between industrial upgrading and ecological quality [21]. In contrast, international research emphasizes industrial ecosystems [22], ecological modernization theory [23], the evolution of industrial ecosystems [24,25], and industry–city symbiosis [26], highlighting the intrinsic linkages between industrial activities and ecological systems from diverse theoretical perspectives.

2.2. Economic and Environmental Impacts of Firm Entry and Exit

Firm Entry and Exit not only shape regional economic structure and industrial dynamics but also influence regional Ecological and Environmental Effects at multiple levels [27]. Firm Entry is often accompanied by expanded production scale and increased factor inputs, which may raise energy consumption, resource use, and pollution emissions, thereby intensifying ecological Pressure. Existing studies show that under stringent environmental regulation, environmental policies significantly affect firms' entry decisions and spatial distribution [28]. In addition, specific policy zones, such as economic development zones, systematically influence firms' environmental performance, further reshaping resource efficiency and pollution emission patterns [29].

At the same time, Firm Exit also exerts significant effects on the ecological environment. Stringent environmental regulation often accelerates the exit of inefficient or highly polluting firms, which helps reduce pollutant emissions, release resource capacity, and improve environmental quality [30,31]. Existing studies further suggest that environmental policies promote regional green transformation and resource reallocation by influencing Firm Exit [32].

2.3. Summary of the Literature and Research Gap

Existing studies primarily examine industrial restructuring, resource–environment interactions, and the environmental implications of firm behavior. Nevertheless, several limitations remain. First, most research focuses on traditional industries and macro-level structures, with insufficient attention to the micro-level dynamics of SEIs' Firm Entry and Exit. Second, methodologically, existing analyses tend to rely on aggregate industrial or regional data, with limited application of firm-level data to construct comprehensive evaluation systems for Ecological and Environmental Effects.

Although some studies have examined the effects of environmental policies on firm behavior, in-depth empirical evidence on how such policies influence Ecological and Environmental Effects through Firm Entry and Exit remains limited. In particular, evidence on regional heterogeneity and spatial spillover effects is fragmented and insufficient, a gap that is especially evident in the context of the evolving spatial configuration of SEIs.

Given these limitations, this study constructs a multidimensional ecological environment evaluation system based on micro-level Firm Entry and Exit data and incorporates regional heterogeneity analysis to systematically examine the Ecological and Environmental Effects of SEIs' Firm Entry and Exit from a firm-dynamics perspective. By doing so, it seeks to fill gaps in the literature regarding research focus, analytical perspective, and spatial mechanism identification.

3. Theoretical Framework and Research Hypotheses

SEIs' Firm Entry and Exit not only reflect regional industrial evolution but also affect Ecological and Environmental Effects through resource reallocation and scale adjustment. From an economic geography perspective, firm dynamics are embedded in regional development stages and path-dependent structures, leading to environmental impacts characterized by structural and regional heterogeneity [33]. Accordingly, this study analyzes these mechanisms from two dimensions—direct effects and structural moderation—and proposes testable research hypotheses.

3.1. Direct Effects of Firm Entry and Exit on Ecological and Environmental Effects

Firm Entry is typically accompanied by expanded production scale and increased factor inputs, which may raise energy consumption, water use, and pollution emissions, thereby intensifying ecological Pressure. In contrast, Firm Exit reduces production scale, helping to lower resource consumption and pollution intensity and thus mitigating Pressure and Destructiveness.

However, SEIs exhibit technological heterogeneity. In regions with higher technological efficiency or stronger governance capacity, new entrants may improve ecological performance through more efficient resource utilization [34]. Therefore, the direction and magnitude of the effects of Firm Entry and Exit across different ecological dimensions remain uncertain [35]. Moreover, Firm Entry and Exit may influence fiscal revenue and spatial resource allocation, thereby reshaping environmental governance capacity and affecting Resilience and Promotion.

3.2. Indirect Effects of Firm Entry and Exit on Ecological and Environmental Effects

Beyond scale effects, Firm Entry and Exit also influence Ecological and Environmental Effects through industrial restructuring and institutional responses. Firm Entry and Exit reshape resource allocation patterns and pollution structures [36], thereby altering interactions among the dimensions of the PSDRP framework.

When firm expansion increases environmental risk, local governments may strengthen regulatory oversight and governance investment [37], whereas Firm Exit may expose legacy pollution and trigger subsequent remediation. These mechanisms indicate that firm dynamics generate multidimensional environmental effects through structural adjustment and institutional adaptation. Given regional differences in development stages and institutional environments, such effects exhibit significant heterogeneity across regions [38].

3.3. Research Hypotheses

Figure 1 illustrates the multidimensional framework of the ecological and environmental effects of firm entry and exit, covering aspects such as resource consumption, pollution

emissions, ecological restoration, and considering the moderating effects of government policies and regional heterogeneity.

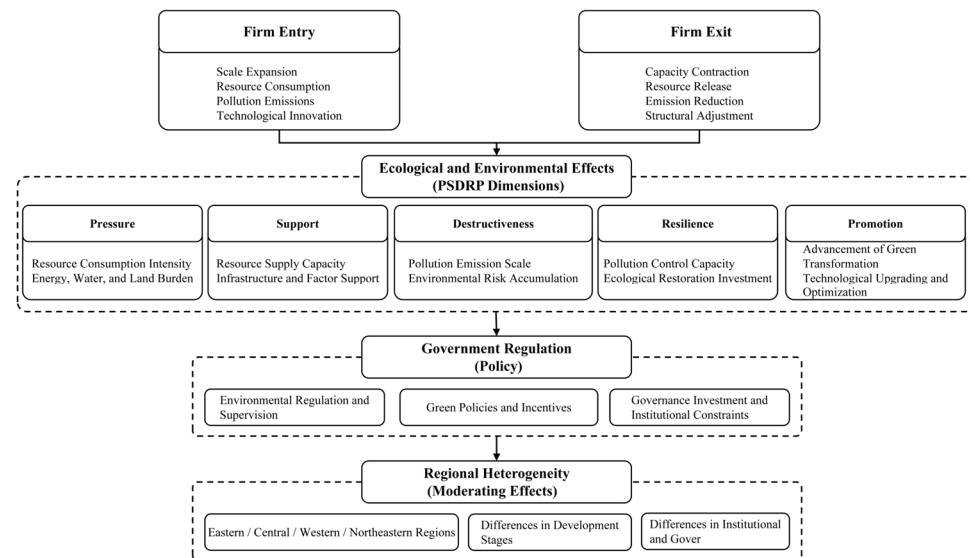


Figure 1. Multidimensional Framework of the Ecological and Environmental Effects of Firm Entry and Exit.

Based on the above analysis, the following hypotheses are proposed:

- H1.** *SEIs' Firm Entry and Exit exert significant effects on regional Ecological and Environmental Effects.*
- H2.** *The direction and magnitude of the effects of SEIs' Firm Entry and Exit differ across the five dimensions of Ecological and Environmental Effects.*
- H3.** *The Ecological and Environmental Effects of SEIs' Firm Entry and Exit exhibit significant regional heterogeneity.*

4. Methodology and Data

4.1. Empirical Strategy

4.1.1. Kernel Density Estimation

Kernel density estimation is a nonparametric method widely used to estimate unknown density functions in geospatial analysis [39]. In this study, kernel density estimation is applied to examine the spatial distribution and agglomeration characteristics of SEIs across China's prefecture-level cities during 2009–2023, thereby identifying the spatial evolution patterns of Firm Entry and Exit. The kernel density function is specified as follows:

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x - x_i}{h}\right)$$

In the above equation, $f(x)$ denotes the kernel density estimate; n represents the sample size; h is the bandwidth parameter; $K(\cdot)$ denotes the kernel function; and x_i indicates the spatial location of each firm. A Gaussian kernel function, as implemented in ArcMap 10.8, is employed to estimate the spatial agglomeration characteristics of SEIs' Firm Entry and Exit.

4.1.2. Panel Fixed-Effects Model

The panel fixed-effects model integrates time-series and cross-sectional data, allowing for effective control of unobserved individual heterogeneity and time-invariant characteristics, thereby improving estimation accuracy. In this study, a panel fixed-effects model is employed to examine the effects of SEIs' Firm Entry and Exit on the five dimensions of Ecological and Environmental Effects [40,41].

The model is specified as follows:

$$Y_{it} = \alpha + \beta_1 \text{Entry}_{it} + \beta_2 \text{Exit}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

In the model, Y_{it} denotes the dependent variable, representing the ecological environment indicator of city i in year t corresponding to Pressure (X1), Support (X2), Destructiveness (X3), Resilience (X4), and Promotion (X5). Entry_{it} and Exit_{it} represent the Number of Entries and Number of Exits, respectively. X_{it} is a vector of control variables, including per capita GDP and population density. α denotes the constant term; β is the vector of coefficients to be estimated; μ_i captures city fixed effects; λ_t captures time fixed effects; and ε_{it} is the error term.

To ensure robust statistical inference, city-level clustered standard errors are employed in all baseline regressions to account for potential within-city correlation in the error terms. The fixed-effects specification controls for unobserved city heterogeneity and time effects, allowing the analysis to focus on the impacts of SEIs' Firm Entry and Exit on the five dimensions of Ecological and Environmental Effects. The estimated coefficients, including their signs and statistical significance, reflect the direction and magnitude of these effects and provide quantitative evidence for urban environmental policy design.

4.2. Data Sources

Firm-level data are obtained from the China National Enterprise Credit Information Publicity System accessed through the Qichacha platform, covering SEIs across China's prefecture-level cities. The database includes approximately 61.23 million registered firms and provides detailed information on firm name, location, establishment date, business scope, industry classification code, and registration status.

According to the national classification standards for Strategic Emerging Industries, SEIs comprise eight sectors: next-generation information technology, high-end equipment manufacturing, new materials, biotechnology, new energy vehicles, new energy, energy conservation and environmental protection, and digital creativity.

Following Mao and Sheng (2013) [42], a firm is classified as a new entrant in year t if it is absent in year $t - 1$ but present in year t . Conversely, a firm is defined as exiting in year t if it is present in year $t - 1$ but absent in year t and all subsequent years. Based on these criteria, a total of 3,286,740 entries, 407,534 exits, and 13,319,932 surviving firms were identified during 2009–2023.

It should be noted that, as the sample ends in 2023, potential right-censoring may arise at the end of the observation period. Firms that do not reappear in 2022–2023 may reflect temporary absence or delayed information updates, introducing uncertainty in identifying late-stage exits. However, since this study focuses on the overall evolution of firm dynamics during 2009–2023 and their long-term Ecological and Environmental Effects, and given that exits are not disproportionately concentrated at the end of the sample period, the resulting bias is likely to be limited. Future research may improve the accuracy of exit identification by incorporating administrative records, such as firm deregistration and bankruptcy filings.

Ecological and environmental data are obtained from the China Statistical Yearbook, China City Statistical Yearbook, China Urban Construction Statistical Yearbook, as well as provincial and municipal statistical yearbooks and official statistical bulletins. Missing

values are supplemented using interpolation methods. Due to data unavailability for Changdu, Nyingchi, Shannan, and Nagqu (Tibet), Haidong (Qinghai), and the regions of Taiwan, Hong Kong, and Macau, the final sample consists of 294 prefecture-level cities.

Although Firm Entry and Exit are identified using firm-level microdata, the analysis focuses on the aggregate Ecological and Environmental Effects of firm dynamics at the city level. Since the PSDRP index is constructed at the city scale, firm-level heterogeneity is not further examined. Future research may construct city-level grouped entry and exit intensities based on sub-industries or firm-size classifications.

5. Spatio-Temporal Evolution Characteristics of SEIs' Firm Entry and Exit in China

To characterize the spatio-temporal evolution characteristics of SEIs' Firm Entry and Exit in China during 2009–2023, the analysis is conducted from three perspectives: temporal trends, distributional patterns, and spatial agglomeration. First, annual trend charts are used to illustrate overall temporal changes in Firm Entry and Exit. Second, based on city-level data, density distribution analysis is employed to examine the evolution of entry and exit intensity across cities. Third, spatial kernel density estimation is applied to identify the geographic agglomeration intensity and expansion processes of Firm Entry and Exit. These complementary analyses provide a multidimensional understanding of the dynamic evolution of SEIs' Firm Entry and Exit.

5.1. Temporal Evolution of Firm Entry and Exit

As shown in Figure 2, SEIs' Firm Entry in China exhibited a sustained upward trend during 2009–2023, with a notable acceleration after 2014, indicating rapid nationwide expansion of SEIs. In contrast, Firm Exit remained at relatively low levels in the early years but began to increase gradually after 2016, with a more pronounced rise after 2018. This pattern suggests that as industry scale expanded and market competition intensified, processes of firm renewal and structural adjustment became increasingly active. Overall, the simultaneous growth in entries and exits reflects a continuous increase in the dynamic activity of SEIs during the study period.

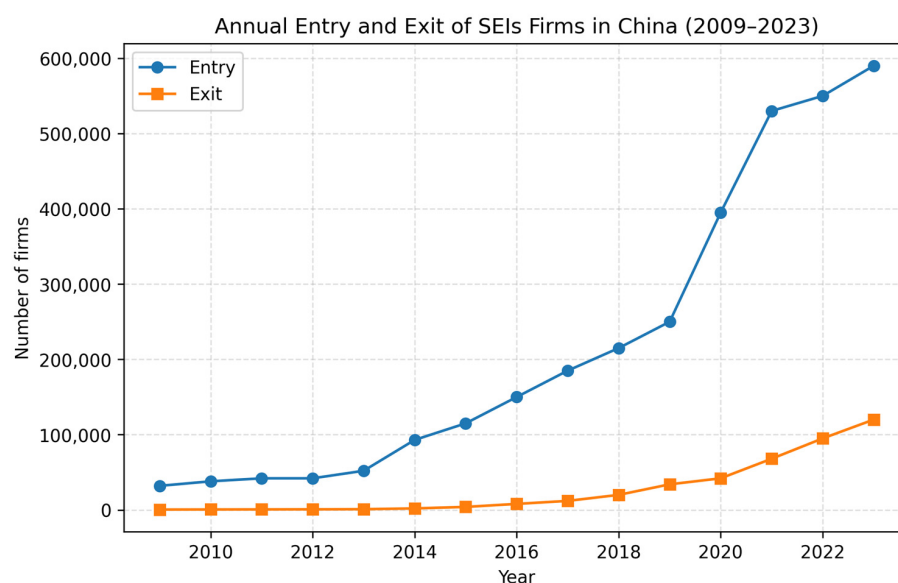


Figure 2. Annual entry and exit of SEIs firms in China (2009–2023).

5.2. Evolution of the Distribution of Firm Entry and Exit

As shown in Figure 3, the city-level intensity of SEIs' Firm Entry exhibits pronounced distributional evolution across years. In the early stage of the study period, Firm Entry was largely concentrated within lower-intensity intervals. Over time, the high-density region gradually shifted toward higher-intensity intervals and expanded outward, suggesting that Firm Entry was no longer driven by a limited number of cities but increasingly extended to a broader set of urban areas. This pattern indicates a nationwide transition of SEIs' Firm Entry from concentration to diffusion.

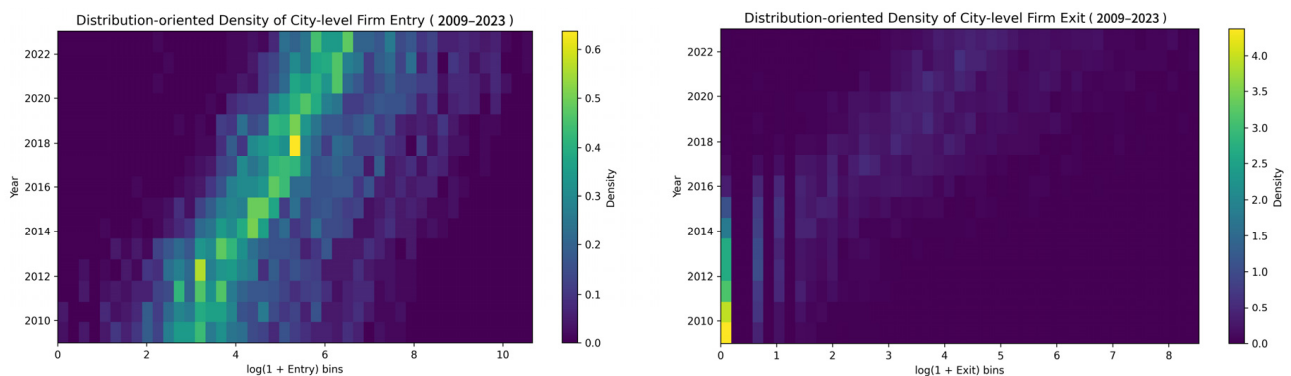


Figure 3. Distribution-oriented density of city-level firm entry and exit (2009–2023).

In contrast, SEIs' Firm Exit remained at relatively low levels across most years and cities, with the distribution largely concentrated within lower-intensity intervals. Accordingly, Figure 3 does not reveal pronounced shifts in peak structures but instead highlights the gradual diffusion of exit behavior to a wider range of cities in the later stages of the study period. Over time, the distribution range of exit intensity expands outward, indicating an increasing spatial prevalence of Firm Exit across cities. This pattern is consistent with the trend reported in Figure 1, where the Number of Exits rises markedly in the later years.

5.3. Spatial Agglomeration Evolution of Firm Entry

Considering the staged development of SEIs and the temporal turning points in Firm Entry and Exit, the period 2009–2023 is divided into three phases: the Initial Agglomeration Phase (2009–2013), the Multi-Point Agglomeration Phase (2014–2018), and the Integrated Agglomeration Phase (2019–2023). This classification captures the evolution of SEIs from early expansion to accelerated agglomeration and subsequent structural adjustment, while providing a unified temporal framework for the phased comparative analysis of Ecological and Environmental Effects.

As shown in Figure 4, during the Initial Agglomeration Phase (2009–2013), SEIs' Firm Entry was primarily concentrated in the Eastern Region, particularly in cities such as Shenzhen and Shanghai, forming several medium-to-high kernel density clusters and exhibiting a distinct point-based agglomeration pattern.

During the Multi-Point Agglomeration Phase (2014–2018), the spatial scope of Firm Entry expanded markedly toward the Central Region, where emerging urban clusters gradually took shape. At the same time, agglomeration intensity in the Eastern core areas further strengthened, resulting in a spatial configuration characterized by a reinforced Eastern core and multi-point growth in the Central Region.

By the Integrated Agglomeration Phase (2019–2023), developed areas in the Eastern Region formed a contiguous high-density belt, while medium-to-high-density clusters in the Central Region became increasingly interconnected. The spatial pattern thus evolved into an “Eastern core–Central linkage” structure. Overall, the agglomeration pattern of SEIs'

Firm Entry shifted from dispersed point-based clusters to more continuous and regionally integrated agglomeration.

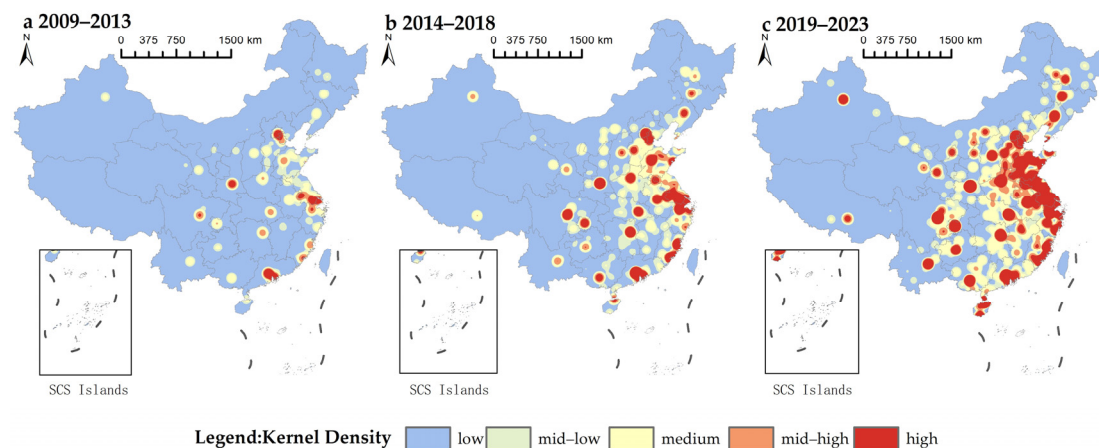


Figure 4. Spatial kernel density map of SEIs' Firm Entry in China (2009–2023). Note: The base map is derived from the Standard Map Service System (Review No.: GS(2024)0650) provided by the Ministry of Natural Resources of the People's Republic of China and has not been modified. Data from [43].

5.4. Spatial Agglomeration Evolution of Firm Exit

As shown in Figure 5, and for consistency with the analysis of Firm Entry, SEIs' Firm Exit is examined across the same three phases. The results indicate that during the Initial Agglomeration Phase (2009–2013) and the Multi-Point Agglomeration Phase (2014–2018), the spatial distribution of Firm Exit closely corresponded to that of Firm Entry. Cities with higher levels of Firm Entry also exhibited relatively high levels of Firm Exit, suggesting a pattern of co-located agglomeration and quantity alignment.

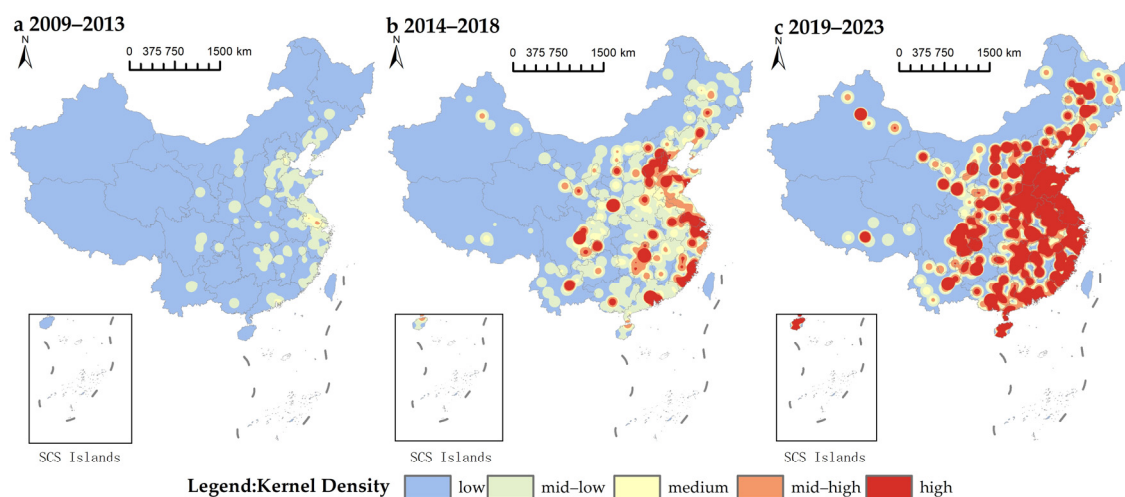


Figure 5. Spatial kernel density map of SEIs' Firm Exit in China (2009–2023). Note: The base map is derived from the Standard Map Service System (Review No.: GS(2024)0650) provided by the Ministry of Natural Resources of the People's Republic of China and has not been modified. Data from [43].

Specifically, major cities in the Eastern Region, such as Shanghai and Shenzhen, ranked among the highest nationwide in both Firm Entry and Firm Exit, reflecting the coexistence of industrial expansion and renewal. In the Central Region, cities including Wuhan and Zhengzhou displayed substantial spatial overlap between entry and exit clusters, indicating a process of natural industrial turnover during the expansion stage.

During the Integrated Agglomeration Phase (2019–2023), the spatial patterns of SEIs' Firm Entry and Firm Exit began to diverge markedly. High-density clusters of Firm Exit

became increasingly concentrated in the Eastern Region, while exit agglomeration in the Central Region and Western Region intensified significantly, gradually forming relatively concentrated high-exit clusters across the Eastern and Central Regions. Meanwhile, the intensity of Firm Exit in the Western Region and Northeast Region exceeded that of Firm Entry during the same period.

Overall, Firm Exit exhibited a broader spatial scope and higher agglomeration intensity, suggesting that during the accelerated industrial restructuring stage, SEIs in certain regions faced more pronounced exit pressures.

The spatio-temporal patterns of SEIs' Firm Entry and Exit in China exhibit both notable commonalities and distinct differences. In terms of common features, both are characterized by spatial agglomeration dominated by the Eastern Region. However, their evolutionary trajectories diverge. Firm Entry displays a stepwise expansion from core areas to peripheral regions, whereas Firm Exit shows intensified concentration in core areas accompanied by diffusion toward a broader spatial range.

Overall, in parts of the Central Region, Western Region, and Northeast Region, the scale of Firm Entry remains relatively limited, while exit trends have become increasingly pronounced. This pattern suggests a strong spatial association between the dynamic evolution of SEIs and regional economic development levels as well as population agglomeration.

6. Quantitative Measurement and Spatio-Temporal Patterns of Ecological and Environmental Effects in China's Prefecture-Level Cities

To systematically characterize the Ecological and Environmental Effects across China's prefecture-level cities and their spatio-temporal evolution, this study first constructs a comprehensive ecological environment evaluation system to quantitatively measure city-level Ecological and Environmental Effects during the study period. This measurement provides a critical foundation for subsequent empirical analysis and facilitates an examination of the interaction between SEIs' Firm Entry and Exit and changes in Ecological and Environmental Effects.

6.1. Construction of the Ecological Environment Evaluation System

Building on the PS–DR–DP hexagonal interaction model of resource–environment carrying capacity proposed by Wang and Liu (2019) [44], this study excludes the “Degradation” dimension to better align with the present research context. On this basis, a five-dimensional ecological environment evaluation system—PSDRP (Pressure, Support, Destructiveness, Resilience, and Promotion)—is constructed, comprising 21 indicators (Table 1).

Table 1. Ecological Environment Evaluation Index System for China's Prefecture-Level Cities.

Target Layer	Influencing Factors	Indicator Layer	Direction
Pressure	Water Resources	Daily Per Capita Domestic Water Consumption (liters)	—
	Land Resources	Area of Farmland Expropriated This Year (square kilometers)	—
	Energy	Annual Electricity Consumption (10,000 kWh)	—
Support	Resource Support	Total Urban Water Supply (10,000 cubic meters)	+
		Total Gas Supply (tons)	+
		Administrative Area Land Area (square kilometers)	+
		Grain Production (10,000 tons)	+

Table 1. Cont.

Target Layer	Influencing Factors	Indicator Layer	Direction
Destructiveness	Atmospheric Environment	Industrial Sulfur Dioxide Emissions (tons)	—
		Industrial Smoke and Dust Emissions (tons)	—
	Water Environment	Wastewater Discharge Volume (10,000 cubic meters)	—
		Industrial Wastewater Discharge Volume (10,000 tons)	—
Resilience	Pollution Treatment Capacity	Industrial Sulfur Dioxide Removal Volume (tons)	+
		Comprehensive Utilization Rate of General Industrial Solid Waste (%)	+
		Household Waste Harmless Treatment Rate (%)	+
		Wastewater Treatment Rate (%)	+
Promotion	Protection and Governance	Per Capita Park Green Space Area (square meters)	+
		Green Coverage Rate in Built-up areas (%)	+
		Landscaping Investment (Ten Thousand Yuan)	+
		Urban Environmental Sanitation Investment (Ten Thousand Yuan)	+

Specifically, Pressure reflects resource consumption intensity; Support captures resource supply capacity; Destructiveness measures pollution emissions; Resilience represents pollution control capacity; and Promotion denotes ecological optimization and environmental improvement.

6.2. Integrated Evaluation Model of Ecological and Environmental Effects

To eliminate differences in measurement scales across indicators, the min–max normalization method is applied to standardize the raw data.

For positive indicators, the standardized form is defined as follows:

$$Z_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)}$$

For negative indicators, the standardized form is defined as follows:

$$Z_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)}$$

Here, X_{ij} denotes the original value of indicator j for city i , and Z_{ij} represents the corresponding standardized value.

To enhance methodological transparency and reproducibility, a simple numerical example is presented. For a positive indicator, namely total urban water supply (min = 100, max = 300), a value of 200 for a given city yields a normalized result of $z = (200 - 100)/(300 - 100) = 0.50$. For a negative indicator, industrial SO_2 emissions (min = 20, max = 80), a value of 60 gives $z = (80 - 60)/(80 - 20) = 0.33$. With entropy weights of 0.55 and 0.45, the aggregated score is calculated as $S = 0.55 \times 0.50 + 0.45 \times 0.33 = 0.425$.

Within the PSDRP framework, Pressure and Destructiveness are treated as negative indicators, whereas Support, Resilience, and Promotion are classified as positive indicators. During the standardization process, negative indicators are transformed inversely to ensure directional consistency, such that higher values uniformly indicate better Ecological and Environmental Performance.

In terms of indicator selection, variables such as electricity consumption and total water supply are used to capture the scale of urban operations and resource demand pressures. Indicators including environmental sanitation investment and pollution control

expenditure are employed to reflect ecological governance capacity and environmental improvement efforts.

This study emphasizes relative differences in indicators across cities and over time. After standardization, the indicators are aggregated for comprehensive evaluation, rather than being used to assess the efficiency of individual components.

Within the PSDRP framework, Pressure and Destructiveness are classified as negative indicators, whereas Support, Resilience, and Promotion are treated as positive indicators.

For indicator weighting, the entropy weighting method is adopted to determine the weight of each indicator. The calculation procedure includes the computation of indicator proportions, estimation of information entropy, and determination of the differentiation coefficient, ultimately yielding the weight W_j for each indicator:

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^n Z_{ij}} \quad E_j = -k \sum_{i=1}^n P_{ij} \ln(P_{ij}) \quad W_j = \frac{1 - E_j}{\sum_{i=1}^m D_j}$$

Based on the calculated weights, a composite index of Ecological and Environmental Effects is constructed through weighted aggregation:

$$RE_i = \sum_{j=1}^M W_j Z_{ij}$$

It should be noted that statistical dimension reduction techniques, such as principal component analysis or factor analysis, are not employed in this study. The five dimensions of the PSDRP framework are grounded in explicit theoretical distinctions intended to capture differentiated forces within the Ecological and Environmental Effects system. Applying statistical dimension reduction could weaken the interpretability of these theoretically defined dimensions. Accordingly, while acknowledging potential correlations among indicators, greater emphasis is placed on theoretical coherence and policy interpretability.

6.3. Spatio-Temporal Patterns of Ecological and Environmental Effects in China

This study applies min–max normalization and the entropy weighting method to construct a composite index of Ecological and Environmental Effects for prefecture-level cities. The data for 2009–2023 are divided into three phases, consistent with the previously identified spatio-temporal evolution stages of SEIs' Firm Entry and Exit, and analyzed separately.

To further examine regional heterogeneity, the analysis adopts China's four-region classification—Northeast Region, Eastern Region, Central Region, and Western Region—as analytical units (Figure 6), based on regional differences in industrial structure and ecological functions. Owing to data availability constraints, Taiwan Province, the Hong Kong Special Administrative Region, and the Macao Special Administrative Region are excluded from the statistical analysis.

As shown in Figure 7, the spatio-temporal evolution of Ecological and Environmental Effects exhibits clear phase-specific characteristics.

During 2009–2013, low- and medium-low-index areas were distributed across all regions, indicating constraints on ecological and environmental improvement, with some areas experiencing deterioration.

In 2014–2018, high-index areas expanded within the Eastern core region and major urban clusters in the Central Region. Meanwhile, low-index areas persisted in ecologically fragile zones of the Western Region and in the Northeast Region, suggesting fluctuations in the improvement process.



Figure 6. Map of China's Four-Region Classification. Note: The base map is derived from the Standard Map Service System (Review No.: GS(2024)0650) provided by the Ministry of Natural Resources of the People's Republic of China and has not been modified. Data from [43].

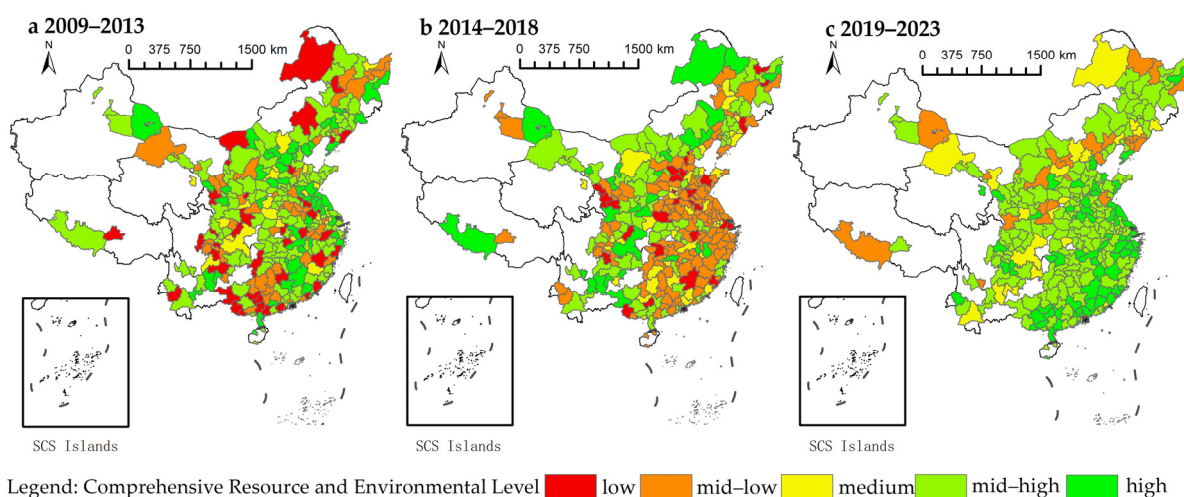


Figure 7. Spatial Distribution of the Composite Ecological and Environmental Effects Index across China's Prefecture-Level Cities in 2009 and 2023. Note: The base map is derived from the Standard Map Service System (Review No.: GS(2024)0650) provided by the Ministry of Natural Resources of the People's Republic of China and has not been modified. Data from [43].

During 2019–2023, contiguous high-index areas further expanded in the Eastern Region, while medium–high-index areas in the Central Region grew rapidly. Although low-index areas in ecologically fragile parts of the Western Region contracted, improvement remained gradual. Low-index areas in the Northeast Region also narrowed. Overall, Ecological and Environmental Effects improved progressively over time, with distinct evolutionary patterns observed across phases.

The spatio-temporal distribution of Ecological and Environmental Effects across China's prefecture-level cities exhibits a notable coupling pattern with the spatio-temporal evolution of SEIs' Firm Entry and Exit. To further quantify the ecological and environmental impacts of industrial dynamics, the subsequent analysis employs a panel fixed-effects model and examines regional heterogeneity across the Eastern Region, Central Region, Western Region, and Northeast Region.

7. Ecological and Environmental Effects of SEIs' Firm Entry and Exit

7.1. Variable Definition and Selection

Table 2 presents the dependent variables, independent variables, and control variables used in this study. The dependent variables include the PSDRP five-dimensional indicators (with a sample size of 4380). The independent variables are Entry (the number of firm entries) and Exit (the number of firm exits), with mean values of 5.128 and 2.370, respectively, indicating a higher degree of dispersion in firm exit numbers, which reflects the dynamic adjustment of industrial layout. The control variables are GDP per capita and population density, which serve as the basis for subsequent analysis.

Table 2. Descriptive Statistics of Variables.

Variable Category	Variable Name	Indicator Description	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Dependent variable	X1	Pressure	4380	0.555	0.077	0.095	0.693
	X2	Support	4380	0.056	0.057	0.003	0.518
	X3	Destructiveness	4380	0.647	0.047	0.269	0.693
	X4	Resilience	4380	0.221	0.125	0.021	0.681
	X5	Promotion	4380	0.449	0.094	0.136	0.693
Independent variable	Entry	Number of enterprises entering	4380	5.128	1.682	0.000	10.658
	Exit	Number of enterprises exiting	4380	2.370	2.045	0.000	8.537
Control variable	lnControl ₁	ln per capita regional GDP	4380	10.719	0.626	8.410	12.486
	lnControl ₂	ln population density	4380	5.721	0.937	1.609	8.008

The selection of control variables follows the “core confounder minimization principle.” GDP per capita reflects the economic development level, which not only directly affects the entry and exit of firms but also has a significant relationship with environmental quality. Population density represents the degree of population agglomeration, which also plays an important role in firm behavior and environmental quality. To avoid potential multicollinearity issues, the model includes city fixed effects and time fixed effects to control for unobservable factors such as institutional, geographical, and industrial conditions, ensuring the robustness of the regression results.

7.2. Benchmark Regression Results

7.2.1. Benchmark Regression

The benchmark regression results (Table 3) show that Entry has a significant negative impact on pressure, supporting power, restoration power, and improvement power, and a significant positive impact on destructive power, indicating that firm entry may increase environmental pressure through greater resource consumption and pollution emissions. However, with technological advancements and increased green investment, firm entry may also enhance ecological restoration to some extent. On the other hand, Exit has a significant positive impact on pressure, supporting power, restoration power, and improvement power, but no significant negative effect on destructive power, suggesting that firm exit can relieve pressure and improve ecological functions but is unable to reverse the legacy environmental damages.

Specifically, the regression results in Table 3 show the following:

Entry has a significant negative effect on pressure and improvement power, especially in eastern and central regions, suggesting that firm entry, particularly in resource-intensive industries, may exacerbate resource consumption pressure but also contribute to improving ecological functions.

Exit has a significant positive effect on supporting power and restoration power, indicating that firm exit releases resources, alleviates ecological pressure, and promotes

ecological recovery. However, its effect on destructive power is not significant, possibly due to the lingering environmental issues that persist after firm exit.

Table 3. Benchmark Regression Results.

	(1)	(2)	(3)	(4)	(5)
	Pressure	Support	Destructiveness	Resilience	Promotion
Entry	−0.006 *** (0.002)	−0.001 ** (0.001)	0.002 ** (0.001)	−0.017 *** (0.004)	−0.007 *** (0.002)
Exit	0.002 ** (0.001)	0.003 *** (0.000)	0.001 (0.000)	0.005 ** (0.002)	0.004 *** (0.001)
Control ₁	−0.003 (0.003)	−0.004 *** (0.001)	0.006 *** (0.002)	−0.071 *** (0.008)	−0.026 *** (0.004)
Control ₂	−0.003 (0.014)	−0.020 *** (0.006)	−0.027 *** (0.008)	0.067 * (0.035)	−0.001 (0.017)
_cons	0.636 *** (0.084)	0.216 *** (0.037)	0.726 *** (0.051)	0.668 *** (0.211)	0.762 *** (0.102)
Observed Values	4380	4380	4380	4380	4380
R ²	0.842	0.943	0.846	0.623	0.842
Adjusted R ²	0.830	0.939	0.834	0.594	0.830
F-Statistic	5.601	18.334	7.940	31.218	21.372
Time Fixed	YES	YES	YES	YES	YES
Subject Fixed	YES	YES	YES	YES	YES

Note: (1) Figures in parentheses represent robust standard errors clustered at the city level; (2) *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

In terms of control variables, GDP per capita (Control₁) has a significant negative effect on supporting power, restoration power, and improvement power, and a positive effect on destructive power, reflecting the complex relationship between economic development and ecological impact. Population density (Control₂) has a significant positive effect on restoration power, indicating that population agglomeration may promote the more efficient use of resources, which in turn contributes positively to ecological restoration. The model shows good fit (R² ranging from 0.623 to 0.943), and the results are robust.

7.2.2. Robustness Test: Sample Trimming

To assess the robustness of the benchmark regression results, this study excludes extreme city-year observations where the number of firm entries and exits falls within the top and bottom 5% of the sample distribution. This approach eliminates outlier interference and simultaneously tests for potential bias in the min-max normalization method when extreme values are present.

The robustness results are presented in Table 4. Overall, the direction of the effects of firm entry and exit on Ecological and Environmental Effects remains consistent with the baseline regression, and the core conclusions are unchanged: firm entry continues to have a significant negative effect on pressure, support, and resilience, while firm exit maintains a significant positive effect on pressure, support, resilience, and promotion. The significance of the key coefficients has not been diminished, indicating the strong robustness of the results.

Furthermore, given the spatial distribution characteristics of firm entry and exit, as well as ecological and environmental effects, potential spatial dependencies should be considered. Due to the focus and limitations of this study, spatial econometric models (e.g., SAR, SEM, or SDM) were not employed for systematic testing. Instead, city and year fixed effects were incorporated to control for unobservable time-invariant spatial heterogeneity. Future research could incorporate spatial weight matrices and spatial panel models to further explore potential spatial spillover effects.

Table 4. Robustness Checks.

	(1)	(2)	(3)	(4)	(5)
	Pressure	Support	Destructiveness	Resilience	Promotion
Entry	−0.007 *** (0.002)	−0.002 ** (0.001)	−0.000 (0.001)	−0.011 ** (0.005)	−0.002 (0.002)
Exit	0.002 ** (0.001)	0.003 *** (0.000)	−0.000 (0.001)	0.008 *** (0.002)	0.002 * (0.001)
Control ₁	−0.009 ** (0.004)	−0.002 (0.002)	0.004 * (0.002)	−0.076 *** (0.009)	−0.029 *** (0.004)
Control ₂	0.009 (0.016)	−0.050 *** (0.008)	−0.016 * (0.009)	0.047 (0.039)	0.007 (0.018)
_cons	0.626 *** (0.099)	0.392 *** (0.049)	0.700 *** (0.058)	0.785 *** (0.250)	0.719 *** (0.117)
Observed Values	3030	3030	3030	3030	3030
R ²	0.863	0.945	0.859	0.639	0.869
Adjusted R ²	0.853	0.941	0.848	0.611	0.858
F-Statistic	6.524	16.675	1.725	22.747	13.197

Note: *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

7.2.3. Robustness Test: Driscoll–Kraay Standard Errors

To further address potential cross-sectional dependence and serial correlation in the panel data, this study re-estimates the baseline model using Driscoll–Kraay standard errors within a two-way fixed-effects model. This approach can simultaneously control for heteroskedasticity, autocorrelation, and cross-sectional dependence, and has been widely used in macro-panel data analysis.

The estimation is conducted using a city–year panel dataset, while controlling for city fixed effects and year fixed effects. The results are presented in Table 5. Overall, the coefficients of Firm Entry and Firm Exit remain largely consistent in both sign and significance with those obtained from the baseline regression. This indicates that the main findings of this study remain robust after accounting for cross-sectional dependence and serial correlation.

Table 5. Robustness Test Using Driscoll–Kraay Standard Errors.

	Pressure	Support	Destructiveness	Resilience	Promotion
ln (Entry)	−0.0092 *** (0.0023)	−0.0020 ** (0.0008)	0.0044 *** (0.0017)	−0.0220 *** (0.0040)	−0.0114 ** (0.0045)
ln (Exit)	0.0018 (0.0018)	0.0033 ** (0.0013)	0.0008 (0.0010)	0.0049 (0.0039)	0.0061 ** (0.0029)
ln (GDP per capita)	−0.0070 (0.0098)	−0.0048 *** (0.0018)	0.0107 *** (0.0032)	−0.0900 *** (0.0193)	−0.0416 *** (0.0063)
ln (Population density)	−0.0206 (0.0194)	−0.0329 * (0.0191)	−0.0463 *** (0.0087)	0.0781 *** (0.0251)	−0.0070 (0.0210)
Controls	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	4380	4380	4380	4380	4380

Notes: The model includes city and year fixed effects. Driscoll–Kraay standard errors are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

7.2.4. Endogeneity Test

To mitigate potential endogeneity arising from firm entry and exit, this study employs the two-stage least squares (2SLS) estimation method. Following related studies, industrial land area and commercial and service land area are selected as instrumental variables and are transformed using $\log(1 + \cdot)$. Changes in land supply structure may influence firm entry and exit by affecting production costs and spatial capacity. After controlling for city fixed effects, year fixed effects, and macroeconomic variables, the impact of land supply on the ecological environment index is expected to operate mainly through the channel of

firm dynamics. Therefore, the instrumental variables are considered to satisfy the relevance and exclusion restrictions.

To enhance transparency, the full first-stage regression results are reported in Appendix A Table A1, including coefficients, clustered standard errors, sample size, and model fit. The results indicate that the instruments are overall relevant to the endogenous variables. Specifically, the first-stage joint F-statistic equals 11.365 for the firm entry equation and 18.433 for the firm exit equation, both exceeding the commonly used threshold for weak instruments.

Table 6 reports the second-stage 2SLS estimation results. The estimated coefficients of firm entry and firm exit exhibit the same signs as those obtained in the baseline panel fixed-effects model, suggesting that the main findings are unlikely to be driven by endogeneity concerns.

Table 6. Second-Stage 2SLS Estimation Results.

Variables	(1)	(2)
ln (Entry)	0.0070 (0.0121)	
ln (Exit)		0.0042 (0.0044)
Per Capita GDP (ln)	0.0007 (0.0056)	0.0029 (0.0035)
Population Density (ln)	−0.0302 (0.0207)	−0.0414 (0.0256)
City Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Sample Size (N)	4275	4275
First-stage Joint F	11.365	18.433
Hansen J (p-value)	N/A	N/A

Note: Robust standard errors clustered at the city level are reported in parentheses.

Because the model includes both city and year fixed effects and employs city-clustered robust standard errors, the Hansen over-identification statistic cannot be computed under the current specification; therefore, it is reported as N/A in the table.

7.3. Regional Heterogeneity Analysis

7.3.1. Mitigation Effects of Strategic Emerging Industries on Ecological and Environmental Pressures

SEIs' Firm Entry and Exit exhibit heterogeneous mitigation effects on ecological and environmental pressure across regions (Figure 7).

For Firm Entry, the mitigation effect follows the order Central Region > Eastern Region > Western Region > Northeast Region. In the Central and Eastern Regions, Firm Entry significantly restrains resource consumption intensity and alleviates ecological pressure. By contrast, the mitigation effect in the Northeast Region is relatively weak, which may be associated with its industrial structure being concentrated in mid- and downstream sectors, relatively weaker innovation capacity, limited diffusion of green technologies, and less stringent resource management.

For Firm Exit, the mitigation effect follows the order Central Region > Eastern Region > Northeast Region > Western Region. The effect in the Western Region is less pronounced, possibly due to the relatively small number and scale of enterprises, resulting in limited resource reallocation following exit. In addition, certain upstream raw material production segments are energy-intensive, and their expansion may partially offset the resource-saving effects generated by firm exit.

7.3.2. Reinforcing Effects of SEIs on Ecological and Environmental Support

The regional heterogeneity results indicate that the impact of SEIs on ecological and environmental support is primarily driven by Firm Exit. Specifically, Firm Exit exerts a

significant positive effect on support across most regions, suggesting that the withdrawal of relatively inefficient firms during industrial restructuring contributes to the enhancement of urban ecological support capacity.

By contrast, Firm Entry exhibits a significant negative effect only in the Eastern Region, implying that large-scale industrial expansion in more developed areas may still impose pressure on resource supply systems. In the Central Region, Western Region, and Northeast Region, the effects of Firm Entry on support are not statistically significant.

7.3.3. Mitigation Effects of SEIs on Ecological and Environmental Destructiveness

The empirical results indicate that the relationship between SEIs' Firm Entry and Exit and ecological and environmental destructiveness is generally weak across the four regions. Only Firm Entry in the Western Region and Firm Exit in the Central Region and Northeast Region exhibit weak statistical significance, with regression coefficients below 0.006. Overall, the magnitude of the estimated effects remains limited, suggesting that SEIs' Firm Entry and Exit exert relatively modest direct influences on destructiveness.

One possible explanation is that SEIs are typically characterized by comparatively lower pollution intensity and may contribute to reducing emissions through technological upgrading. Moreover, SEIs may weaken destructiveness indirectly by substituting traditional high-pollution industries. However, this substitution effect is not directly tested in the present study and thus remains speculative. Future research could further examine this mechanism through comparative analysis between SEIs and traditional industries.

7.3.4. Heterogeneous Effects of SEIs on Ecological and Environmental Resilience

The results indicate that SEIs' Firm Entry and Exit do not exhibit a uniformly significant positive relationship with ecological and environmental resilience. Firm Entry in the Central Region and Western Region is associated with a reduction in resilience, whereas Firm Exit in the Eastern Region and Central Region contributes to its improvement.

Further examination suggests that the relationship between SEI development and resilience is particularly complex in the Central and Western Regions. First, the incremental scale of SEIs may be insufficient to substantially reduce the stock of high-pollution traditional industries, and in some cases may introduce additional resource pressure. Second, fragmentation between clean production, pollution generation, and pollution treatment processes—together with infrastructure constraints—may limit improvements in environmental recovery capacity.

Moreover, part of the SEI expansion in the Central and Western Regions is related to industrial transfer from the Eastern Region. Some transferred segments may include pollution-intensive or resource-intensive production stages (e.g., silicon material processing and bio-fermentation), which are often water-intensive and may exacerbate local resource and ecological pressures. These structural factors may partially offset the potential positive effects of SEIs on resilience.

7.3.5. Indirect Effects of SEIs on Ecological and Environmental Promotion

The theoretical expectation is that SEIs may influence ecological and environmental promotion indirectly. Specifically, the development of SEIs can enhance urban economic vitality and overall output, and higher levels of economic development may, in turn, contribute to improvements in ecological and environmental quality.

However, the empirical results (Figure 8) do not provide clear statistical support for this indirect channel. In the Eastern Region, the relationship between SEIs' Firm Entry and Promotion is not statistically significant. In the Central Region and Western Region, Firm Entry is associated with a reduction in promotion, whereas in the Northeast Region, Firm Exit is positively associated with promotion.

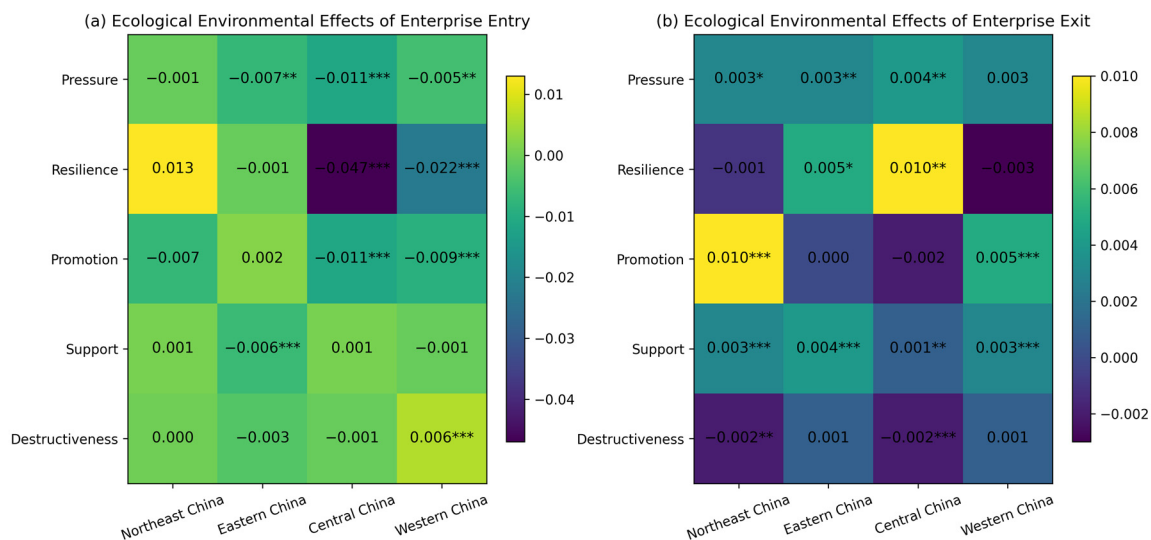


Figure 8. Regional Heterogeneity Heatmap of the Ecological and Environmental Effects of SEIs' Firm Entry and Exit. Note: *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

These findings suggest that the expected indirect pathway through which SEIs stimulate ecological and environmental promotion has not yet been fully realized across regions.

7.4. Mechanism Analysis of Ecological and Environmental Effects of Firm Entry and Exit in Strategic Emerging Industries

To further identify the pathways through which firm entry and exit affect ecological and environmental effects, this study adopts the PSDRP framework and divides ecological and environmental effects into five dimensions, namely Pressure, Support, Destructiveness, Resilience, and Promotion, each of which is examined through regression analysis. The results in Table 3 and Figure 8 show that the direction and significance of the effects of firm entry and exit vary across these dimensions, allowing the potential mechanisms to be identified empirically. Figure 9 provides a summary of these relationships. A brief calculation example is provided in Section 6.2.

Regarding firm entry, the results indicate clear regional differences in ecological and environmental effects. In the Eastern Region, firm entry significantly reduces resource consumption intensity but increases overall resource demand and pollution emissions to some extent, suggesting the coexistence of technological advantages and expansion effects. In the Central Region, firm entry strongly restrains resource consumption, yet large-scale industrial expansion occupies ecological space and constrains ecological resilience, while investment in specific technological paths may hinder the iteration of green technologies. In the Western Region, firm entry is more concentrated in resource-intensive industries, increasing pressure on ecological space and resource competition and thereby intensifying environmental burdens. In the Northeast Region, due to weaker green technology transformation, newly established firms tend to be smaller in scale, and their contribution to ecological improvement remains limited.

Regarding firm exit, the ecological and environmental effects mainly operate through resource reallocation and adjustments in pollution emissions. In the Eastern Region, firm exit releases resources and promotes the concentration of environmentally friendly industries, enhancing ecological recovery capacity, although historical pollution problems still exist in some areas. In the Central Region, firm exit significantly reduces pollution emissions and releases resource space, supporting ecological recovery. In the Western Region, firm exit helps optimize industrial spatial structures and provides opportunities

for environmental governance and industrial upgrading. In the Northeast Region, firm exit reduces pollution emissions, but ecological recovery remains constrained by historical environmental problems and insufficient governance investment.

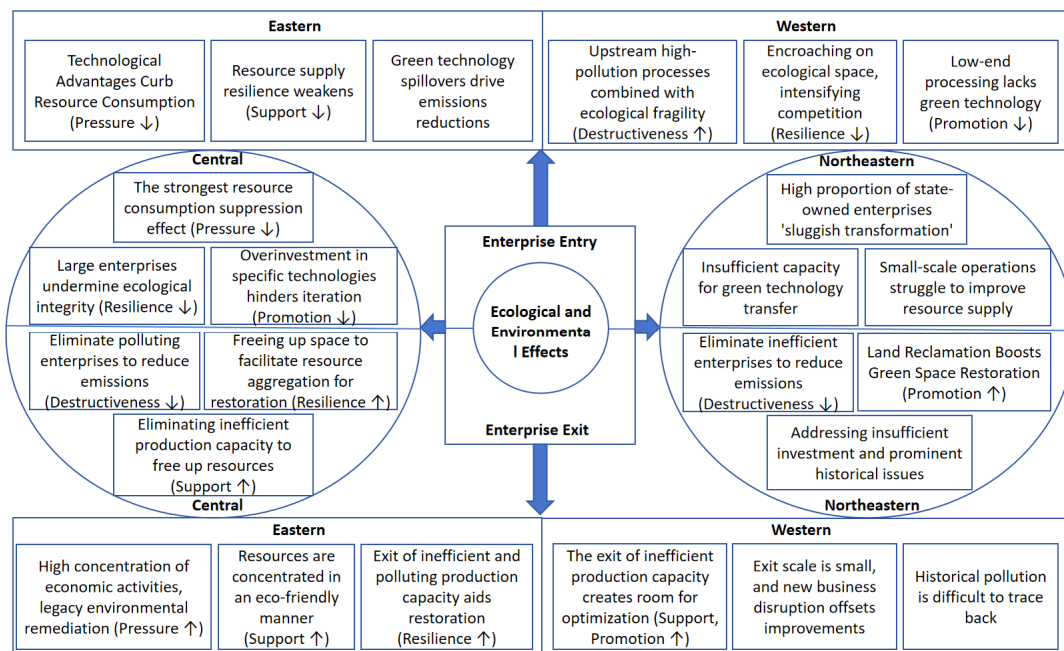


Figure 9. Mechanism framework of ecological environmental effects of enterprise entry and exit.

Overall, firm entry and exit influence ecological and environmental effects through resource reallocation, technological diffusion, and structural adjustment. Figure 9 summarizes these mechanisms.

It should be emphasized that this study validates the pathway effects depicted in the conceptual mechanism framework by conducting regression analyses on the impacts of firm behavior across the five PSDRP dimensions, rather than employing additional mediation models. This multidimensional regression approach facilitates the identification of heterogeneous ecological and environmental effects under varying regional conditions and industrial dynamics.

7.5. Discussion

Through the analysis presented in this study, the core hypothesis is largely supported: the entry and exit of strategic emerging industry (SEIs) enterprises exert significant and multidimensional impacts on regional ecological environmental performance. However, whether enterprise entry necessarily leads to environmental improvement still requires careful interpretation. Due to differences in regional development stages and local conditions, the ecological environmental effects generated by enterprise entry and exit vary considerably across regions.

In the eastern region, enterprise entry significantly alleviates resource consumption pressure. This outcome is closely related to the widespread adoption of cleaner technologies and more advanced pollution control systems. Meanwhile, enterprise exit releases production space and resources, facilitating the development of environmentally friendly industries and further strengthening ecological restoration capacity. In contrast, the situation in central and western regions is more complex. Although enterprise entry can help restrain resource consumption, if newly established firms are concentrated in energy-intensive or resource-dependent sectors, ecological pressure may increase and environmental recovery capacity may be weakened. The northeastern region faces more structural constraints.

Enterprises are generally smaller in scale and often located in downstream segments of industrial chains, while the transformation capacity of green technologies remains limited. As a result, enterprise entry plays a relatively weak role in alleviating ecological pressure. At the same time, insufficient investment in the remediation of abandoned industrial sites limits the ecological benefits generated by enterprise exit.

These regional differences suggest that policy design should consider both technological thresholds and environmental governance mechanisms. When encouraging enterprise entry, governments should pay greater attention to technological standards and environmental requirements. When promoting enterprise exit, it is equally important to address legacy environmental problems in order to ensure that industrial restructuring effectively contributes to ecological improvement. Specifically, the eastern region should further promote clean technologies and environmental governance. The central and western regions should avoid excessive dependence on energy-intensive industries while strengthening ecological restoration capacity. For the northeastern region, enhancing green technological innovation and accelerating industrial upgrading are particularly critical.

In addition, enterprise entry and exit may generate spatial spillover effects through industrial linkages, factor mobility, and pollution diffusion. Due to limitations in the scope of this study, these spatial transmission mechanisms have not been explicitly modeled. Future research could incorporate spatial econometric approaches, such as spatial lag models or spatial error models, to better capture cross-regional interactions.

Although this study focuses primarily on macro-level analysis, future research could further explore firm heterogeneity within SEIs. Differences in firm size, ownership structure, and sub-industry characteristics may lead to varying ecological environmental outcomes during the processes of enterprise entry and exit. Incorporating factors such as firm age, size classification, or sectoral distinctions would help provide a more nuanced understanding of environmental impacts.

Finally, this study mainly examines the ecological environmental consequences of enterprise entry and exit, while potential economic outcomes—such as productivity improvements, employment creation, and fiscal contributions—are not explicitly analyzed. Environmental improvements may increase compliance costs in the short term, yet in the long run, green innovation and optimized resource allocation may generate positive economic returns. Future research could therefore explore the potential synergies and trade-offs between environmental and economic effects, providing more comprehensive evidence for policy making.

8. Conclusions

8.1. Conclusions

- (1) The spatial patterns of SEIs' Firm Entry and Exit in China exhibit both commonalities and distinctions. In terms of common features, both patterns are characterized by concentration in the Eastern Region with gradual westward diffusion, with the Eastern Region maintaining a dominant position in both dynamics. However, notable differences emerge: the spatial pattern of Firm Entry displays a stepwise expansion from core to peripheral areas, whereas Firm Exit demonstrates a pattern of core intensification accompanied by broader diffusion. Compared with entry, exit exhibits stronger agglomeration intensity and wider spatial coverage.
- (2) The dynamic evolution of SEIs' spatial patterns in China exhibits clear economic, demographic, and innovation-oriented characteristics. The Eastern Region records the highest volume of firm entry, while firm exit increasingly shifts toward the Central and Western Regions. In contrast, the Western, Northeastern, and even relatively developed Central Regions primarily undertake industrial transfers from the east.

In these areas, firm entry remains limited, whereas exit pressures have intensified over time.

- (3) Resource and environmental levels across Chinese cities have shown a steady upward trend over the study period. Their spatial distribution demonstrates evident coupling characteristics with the spatial configuration of SEIs' Firm Entry and Exit.
- (4) The Ecological and Environmental Effects of SEIs' Firm Entry and Exit are inherently multidimensional, although certain dimensions have not yet fully materialized. Specifically, SEIs exhibit a mitigating effect on ecological Pressure, a reinforcing effect on Support, a limited weakening effect on Destructiveness, a reverse effect on Resilience, and an indirect effect on Promotion. However, the indirect effect has not yet become statistically evident at China's current stage of development.
- (5) The Ecological and Environmental Effects of SEIs' Firm Entry and Exit exhibit pronounced regional heterogeneity. In the Eastern Region, industrial upgrading enables the coordinated effects of Firm Entry and Exit to alleviate ecological Pressure while enhancing Support and Promotion capacities. In the Central and Western Regions, the introduction of green industries significantly restrains resource consumption and strengthens Resilience; however, the expansion of resource-intensive segments intensifies ecological competition and potential risks. In the Northeast Region, sluggish industrial restructuring results in limited mitigation of ecological Pressure from Firm Entry and insufficient improvement in Resilience from Firm Exit, compounded by lagging remediation of historical pollution. These differentiated dynamics ultimately form a pattern characterized by "optimization in the Eastern Region, improvement with structural risks in the Central and Western Regions, and persistent adjustment challenges in the Northeast Region."

8.2. Policy Implications

Based on the baseline regression results, regional heterogeneity analysis, and mechanism tests, several policy implications can be derived.

First, improving the quality of firm entry in Strategic Emerging Industries (SEIs) is essential.

The results show that firm entry has multidimensional effects on ecological and environmental effects. While promoting industrial development, policymakers should raise technological and environmental standards to encourage the entry of low-emission, energy-efficient, and high-technology firms. This would help avoid excessive concentration of resource-intensive industries and promote coordination between industrial development and ecological environmental protection.

Second, it is necessary to strengthen the linkage between firm exit and environmental governance.

The empirical findings indicate that firm exit can reduce pollution emissions and release resources, yet historical environmental problems still exist in some regions. Therefore, policies should promote the market-oriented exit of inefficient firms while simultaneously strengthening environmental remediation and site restoration so as to achieve coordinated progress in industrial restructuring and ecological recovery.

Third, differentiated regional development policies should be implemented.

The heterogeneity analysis suggests that the ecological environmental effects of firm entry and exit vary significantly across regions. The Eastern Region should further promote green technological diffusion and industrial upgrading. The Central Region and the Western Region should strengthen environmental constraints when undertaking industrial transfer to prevent excessive expansion of energy-intensive industries. Meanwhile, the

Northeast Region needs to accelerate industrial restructuring and enhance its capacity for green technological innovation.

Finally, greater coordination between industrial policy and environmental policy is required.

The mechanism analysis indicates that firm entry and exit influence ecological environmental performance through resource allocation, technological innovation, and structural adjustment. Therefore, environmental considerations should be more fully integrated into industrial development policies. Policy tools such as innovation support, green finance, and environmental governance investment can facilitate industrial upgrading while simultaneously improving ecological environmental performance.

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Appendix A

Table A1. First-stage Regressions (IV = log (1 + land)).

Variables	(1) ln (Entry)	(2) ln (Exit)
Industrial land (log1p)	0.0325 (0.0251)	0.0512 (0.0482)
Commercial and service land (log1p)	0.0588 ** (0.0262)	0.1621 *** (0.0591)
Per capita GDP (ln)	0.3880 *** (0.0589)	0.0976 (0.1298)
Population density (ln)	0.2064 (0.2501)	2.9490 *** (0.5597)
City Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Sample Size (N)	4275	4275
R-squared	0.967	0.913

Note: Robust standard errors clustered at the city level are reported in parentheses. ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

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