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Article

Evaluation of Sustainable Development in China's Pilot Free Trade Zones

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Abstract

The essence of free trade zones lies in addressing development challenges through institutional opening-up and innovation-driven growth. Sustainable development constitutes the fundamental goal of free trade zone construction, opening-up and innovation serve as the core driving forces for their development, and a sound business environment acts as a critical guarantee for their efficient operation. Therefore, based on the panel data of 22 free trade zones in China from 2013 to 2022, this paper adopts Principal Component Analysis (PCA) and Analytic Hierarchy Process (AHP) to conduct a comprehensive evaluation of their sustainable development levels from six dimensions: environmental optimization, economic development, opening-up, radiation-driven capacity, business environment, and scientific and technological innovation. The results indicate that, first, the overall comprehensive scores of free trade zones in sustainable development show an upward trend with obvious regional divergence in growth rates. Coastal free trade zones maintain robust growth momentum, inland ones achieve steady progress, and border free trade zones witness modest growth. Second, the comprehensive scores of the 22 free trade zones in 2022 present a gradient distribution, reflecting prominent regional development imbalance. On this basis, targeted policy recommendations are put forward in this paper.

Keywords: free trade zone; principal component analysis; analytic hierarchy process; sustainable development

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1. Introduction

Since the establishment of the Shanghai Pilot FTZ in 2013, China's national FTZ strategy has advanced steadily. By 2023, a nationwide network comprising 22 FTZs had taken shape. This strategic layout aims to promote regional economic development and strengthen China's position in the global economic landscape through institutional innovation and open cooperation. Each FTZ was assigned distinct strategic roles and functional priorities at inception. For example, the Shanghai FTZ focuses on high-end services such as finance and shipping, aiming to become an internationally influential financial center and trade hub. The Guangdong FTZ emphasizes deep integration among Guangdong, Hong Kong, and Macao, advancing service-sector market unification and trade facilitation. The Hainan Free Trade Port strives to develop into an international tourism and consumption center with high-level trade and investment liberalization and facilitation. These differing mandates and functional requirements render single-dimensional evaluation indicators inadequate for accurately measuring performance—underscoring the necessity of constructing a multidimensional evaluation framework. Due to variations in geographical location, resource endowments, industrial foundations, and economic development levels, FTZs face diverse opportunities and challenges. Relying solely on partial or narrow indicators risks misjudging strengths and weaknesses, thereby compromising the scientific rigor and rationality of policy design and resource allocation. A multidimensional evaluation system enables holistic, objective assessment aligned with each FTZ's unique characteristics and developmental direction—supporting

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differentiated, distinctive, and sustainable development, and fostering coordinated progress and complementary advantages across regions.

2. Literature Review

China's Pilot Free Trade Zones (FTZs), as key platforms for deepening reform and expanding openness, have become prominent subjects of academic and practical research.

As China's FTZ strategy progresses, domestic and international scholars continue refining comprehensive evaluation frameworks. Diverse disciplinary backgrounds and practical needs have led to varied research emphases. Some scholars focus on environmental aspects, examining links between FTZ establishment and sustainable development. Caiyan Jia and Yiran Hua (2024) analyzed data from 281 prefecture-level Chinese cities and found that FTZ policies significantly curb local environmental pollution. Liming Xiao and Ying Zhang (2025) systematically assessed FTZs' impacts on air pollution and carbon emissions, mechanisms involved, and spatial spillover effects—concluding that FTZs contribute to urban emission reductions and decarbonization. Others concentrate on economic development, investigating FTZs' role in boosting regional growth. Dongyang Qiu et al. (2022) studied the first three batches of 11 provincial FTZs (2013–2017), finding robust positive effects on regional GDP growth—with stronger outcomes observed in coastal provinces than inland ones, and relatively greater impacts in northeast and central provinces compared to western ones. M. Zhang et al. (2022) applied a difference-in-differences (DID) model to central and western FTZs (2010–2019), confirming significant positive effects on regional sustainable development, with clear regional disparities in sustainability levels.

Meanwhile, scholars have examined openness-related dimensions. T. Bao et al. (2023) investigated how FTZs affect capital flows, imports and exports, and underlying mechanisms—finding that FTZs stimulate both foreign direct investment (FDI) and outward FDI. Guigu Ye et al. (2024) analyzed 25 major coastal ports and concluded that FTZ initiatives enhance port logistics efficiency and thus support foreign trade expansion. Others explore radiating and driving effects—the extent to which FTZs spur economic linkage and coordinated development in surrounding areas. Yafei Wang et al. (2023) found that FTZ establishment significantly boosts green total-factor productivity in host cities and generates positive spatial spillovers, improving productivity in neighboring cities. H. Mahmood (2023), using a spatial Durbin model for 18 Latin American countries (1970–2019), showed that FDI yields positive environmental externalities for neighboring economies and the broader region—even if domestic imports lack such effects.

Some researchers emphasize the business environment, evaluating how policy conditions influence enterprise development. Haiying Zhufu et al. (2023) assessed the business environment across 11 zones of the Yellow River Basin FTZ Alliance using five indicators—including tax incentives, commercial circulation capacity, and financial service innovation. Y. Wang and Q. Kong (2024), analyzing A-share listed firms in Shanghai and Shenzhen (2010–2022), found FTZ establishment significantly improves corporate financial health and business environment quality—enhancing enterprise sustainability. FTZs aim to improve the business environment by strengthening intellectual property protection, advancing rule-of-law governance, and building more transparent and efficient market supervision systems—thereby supporting high-tech and large-scale enterprises. Zhendong Su et al. (2025) constructed a provincial-level business environment evaluation index using entropy weighting, revealing that FTZ construction positively reshapes interprovincial business environment networks. Others examine scientific and technological innovation, assessing FTZs' role in promoting tech advancement and industrial upgrading. Wei Wei et al. (2024) demonstrated that FTZ policies boost urban innovation capacity by attracting talent and optimizing institutional environments. S. Xu et al. (2024), using provincial panel data (2006–2019), confirmed that FTZ establishment improves regional innovation efficiency. Collectively, these studies offer rich theoretical grounding and empirical reference for FTZ evaluation.

Yet, single-dimensional assessments cannot fully capture the complex, multifaceted impacts of FTZs as laboratories for institutional innovation. Thus, some scholars construct holistic indicator systems for comprehensive evaluation. Bifei Tian and Wei Li (2015) introduced the first FTZ construction demand framework, developing evaluation indices for “FTZ construction foundations” and “inland FTZ construction demands,” applying them to Wuhan as a case study. Mingqiang Xu, Dahai Dong, and Baishu Chang (2020) evaluated FTZ development levels across economic, ecological, and technological dimensions, constructing an index system to preliminarily assess Shanghai, Tianjin, Guangdong, and Fujian FTZs. Yu Zhu (2021) compared domestic and international FTZs across six domains: incentives, infrastructure, costs, transport, promotion strategies, and services. Junpu Shi (2024) evaluated Heilongjiang FTZ sustainability across five dimensions—innovation, coordination, green development, openness, and shared prosperity.

3. Framework Construction for Evaluating Sustainable Development in FTZs

As China’s frontier for deepening reform and expanding openness, FTZ development levels bear not only on regional growth but also on national strategic objectives. A comprehensive, systematic evaluation framework thus provides objective evidence for government decision-making, enterprise investment, and public oversight—supporting sustainable FTZ development.

3.1. Content of the Evaluation Framework

The state consistently positions FTZs as pivotal supports for deepening reform and expanding openness. Following the Shanghai FTZ pilot launch in 2013, successive policies expanded FTZ coverage, accelerated institutional breakthroughs, and explicitly required alignment with high-standard international economic and trade rules—prioritizing institutional openness and piloting reforms in factor mobility, science-technology integration, and business environment enhancement. The 20th CPC National Congress further emphasized “advancing high-level institutional openness” and “implementing the FTZ enhancement strategy”—guiding FTZs toward higher-quality development and innovation-driven advancement. As core experimental platforms for national reform and opening-up, FTZs achieve efficient factor allocation via dual drivers—openness and innovation—delivering multi-dimensional gains: upgraded economic performance, regional coordination, and ecological optimization. Hence, FTZs fundamentally address development quality issues through institutional openness and innovation; sustainable development outcomes represent their ultimate purpose; openness and innovation form their core methods; and a sound business environment ensures operational efficiency. Therefore, FTZ sustainable development is assessed across six dimensions: environmental improvement, economic development, opening-up to the outside world, radiating and driving effects, business environment, and scientific and technological innovation.

Environmental improvement is both an essential political task reflecting ecological civilization principles and a strategic choice vital to sustaining competitiveness—making its inclusion in the evaluation framework indispensable. It is measured through two aspects: environmental governance and greening efforts. Environmental governance relies on four indicators: wastewater discharge and industrial SO_2 emissions as shares of GDP; ratio of industrial solid waste reused to generated; and investment in industrial pollution control. Greening efforts use five indicators: green coverage ratio in built-up areas; per capita park area; centralized sewage treatment rate; harmless disposal rate of domestic waste; and forest coverage rate.

Table 1. cators for Environmental Improvement in FTZs.

Secondary Indicators	Tertiary Indicators	Specific Indicators
Environmental Optimization	Environmental Governance	Total wastewater discharge / GDP (%)
		Industrial SO_2 emissions / GDP (%)

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Secondary Indicators	Tertiary Indicators	Specific Indicators
		Comprehensive utilization rate of industrial solid waste (%)
		Investment in industrial pollution control (10,000 yuan)
		Green coverage rate of built-up areas (%)
		Per capita park green area (m²/person)
	Greening Construction	Centralized treatment rate of sewage treatment plants (%)
		Harmless treatment rate of domestic garbage (%)
		Forest coverage rate (%)

Economic development directly reflects FTZs' core functions—trade facilitation and investment liberalization—and serves as a visible benchmark of open-economy competitiveness. Its inclusion in the evaluation framework is therefore essential. Economic development is assessed across four aspects: economic performance, industrial structure, urban-rural coordination, and welfare levels. Economic performance uses four indicators: gross regional product (GRP), total retail sales of consumer goods, fixed asset investment, and general public budget expenditures. Industrial structure is evaluated via two indicators: structural rationality and structural sophistication. Urban-rural coordination is gauged by urbanization rate and urban-rural coordination index. Welfare level covers employment, livelihood, education, and healthcare—measured respectively by employment volume, Engel coefficient, college students per 10,000 people, and hospital beds per 10,000 people.

Table 2. ndicators for Economic Development in FTZs.

Secondary Indicators	Tertiary Indicators	Specific Indicators
		Regional Gross Domestic Product (100 million yuan)
	Economic Operation	Total Retail Sales of Consumer Goods (100 million yuan)
		Completed Investment in Fixed Assets (100 million yuan)
Economic Development		General Public Budget Expenditure (100 million yuan)
	Industrial Structure	Rationalization of Industrial Structure
		Advancedization of Industrial Structure
		Urbanization Rate (%)

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Secondary Indicators	Tertiary Indicators	Specific Indicators
	Urban-Rural Structure	Urban-Rural Coordination Degree
	Welfare Level	Employment Scale (10 thousand persons)
		Engel Coefficient
		Number of College Students per 10,000 Population
		Number of Medical Beds per 10,000 Population

Opening-up to the outside world defines FTZs' core identity as "pioneering experimental fields." It embodies national openness strategy, manifests trade facilitation and investment liberalization, and forms the foundational basis ensuring replicability and scalability of institutional innovations. Thus, it constitutes a core evaluation dimension. Opening-up is assessed across two aspects: scale and quality. Scale is measured by total import-export value and import-export value by destination/source within China. Quality is gauged by the Trade Competitiveness (TC) index, foreign investment dependency ratio, and outward FDI.

Table 3. Indicators for Opening-up in FTZs.

Secondary Indicators	Tertiary Indicators	Specific Indicators
Opening-up	Scale of Foreign Trade	Total import and export volume (thousand US dollars)
		Total import and export volume by domestic destination and source of goods (100 million yuan)
	Quality of Foreign Trade	Trade Competitiveness Index (TC Index)
		Foreign capital dependence
		Outward Foreign Direct Investment

Radiating and driving effects reflect FTZs' strategic mandate to "lead by example." These effects enable replication of institutional innovations in surrounding areas, drive factor mobility and regional upgrading, and signal leadership over regional economies—making them a vital sustainability indicator. Radiating and driving capacity is assessed across two aspects: overall driving capacity [16] and industrial driving capacity [16]. Overall driving capacity uses per capita disposable income and consumer price index (CPI). Industrial driving capacity relies on three indicators: added value of transportation, storage, and postal services; added value of financial services; and passenger turnover volume—each expressed as a share of GDP.

Table 4. Indicators for Radiating and Driving Capacity in FTZs.

Primary Indicators	Secondary Indicators	Tertiary Indicators
		Per capita disposable income

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Primary Indicators	Secondary Indicators	Tertiary Indicators
Radiation-driven Capacity	Overall Driving Capacity	Consumer Price Index (CPI)
	Industrial Driving Capacity	Added value of transportation, warehousing and postal industry / GDP
		Financial industry added value / GDP
		Passenger turnover volume (100 million passenger-kilometers)

The business environment underpins FTZs' ability to leverage openness advantages and implement institutional innovations. A high-quality environment attracts foreign investment and premium enterprises—directly enhancing open-economy effectiveness—and visibly reflects the success of "pioneering experiments." Hence, it ranks among key evaluation indicators. It is assessed across five aspects: trade facilitation, investment liberalization, infrastructure development, financial innovation, and regulatory systems. Trade facilitation is measured by registered capital of foreign-invested enterprises, number of such enterprises, and their total import-export value. Investment liberalization uses two indicators: incremental social financing scale and fiscal expenditure as share of GDP. Infrastructure development is gauged by broadband access ports, gas supply capacity, and water supply volume. Financial innovation uses four indicators: loan balance of financial institutions relative to GDP; local science-and-technology fiscal spending relative to local general budget expenditures; deposit balance of financial institutions; and total social debt relative to GDP. Regulatory capacity is reflected by local fiscal spending on financial regulation.

Table 5. Indicators for Business Environment in FTZs.

Secondary Indicators	Tertiary Indicators	Specific Indicators
Business Environment	Trade Facilitation	Registered capital of foreign-invested enterprises (million US dollars)
		Number of foreign-invested enterprises (households)
		Total import and export volume of foreign-invested enterprises (thousand US dollars)
	Investment Liberalization	Increment in aggregate social financing (100 million yuan)
		Market vitality index
	Infrastructure Construction	Number of broadband internet access ports (10 thousand units)
		Gas supply capacity (10 thousand tons)
		Total water supply (10 thousand cubic meters)

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Secondary Indicators	Tertiary Indicators	Specific Indicators
	Financial Innovation	Outstanding loans of financial institutions / GDP (%)
		Local fiscal expenditure on science and technology / local general budget expenditure
		Deposit balance of financial institutions (100 million yuan)
	Supervision Level	Local fiscal expenditure on financial supervision (100 million yuan)

Scientific and technological innovation forms the core engine of FTZ sustainable development—supporting industrial upgrading toward high-end, intelligent production and enhancing FTZs' competitiveness in the open economy—thus qualifying as a critical evaluation dimension. Innovation capacity is assessed across two aspects: innovation input and output. Input is measured by R&D expenditure and number of people with associate degrees or higher per 10,000 population. Output is gauged by new product sales revenue of high-tech industries and technology market transaction value.

Table 6. Indicators for Scientific and Technological Innovation Capacity in FTZs.

Primary Indicators	Secondary Indicators	Specific Indicators
Scientific and Technological Innovation	Innovation Input	Number of population with college education or above per 10,000 people
		R&D expenditure (10,000 yuan)
	Innovation Output	Transaction value of technology market (100 million yuan)
		Sales revenue of new products in high-tech industries (10,000 yuan)

Data for the above indicators derive primarily from panel data covering China's 22 FTZs from 2013 to 2022, sourced from the China Statistical Yearbook (2013–2022), provincial statistical yearbooks (2013–2022), and official statistical bulletins.

3.2. Methodology for Calculating Sustainable Development Scores

To scientifically measure the sustainable development levels of the 22 FTZs from 2013 to 2022, this study firstly adopts the principal component analysis (PCA) to reduce dimensionality and assign objective weights to the underlying indicators under the six secondary dimensions, so as to calculate the dimensional comprehensive scores of each FTZ. Secondly, the analytic hierarchy process (AHP) is applied to determine the weight of each secondary indicator for the overall evaluation objective. Finally, linear weighting is conducted to integrate the two sets of weighting results and obtain the final comprehensive scores of sustainable development.

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3.2.1. PCA-Based Calculation of Underlying Indicator Composite Scores

Principal Component Analysis can simplify multiple correlated indicators into a small number of independent comprehensive variables while retaining the information of original variables to the greatest extent. It assigns objective weights according to the variance contribution rate of each principal component, thereby effectively avoiding biases caused by subjective weighting.

(1) Data Preprocessing

Step1: indicator positive normalization. Negative and moderate indicators are converted into positive ones, where a higher value indicates a better performance.

In this paper, five negative indicators, namely the ratio of industrial wastewater discharge to GDP, the ratio of industrial sulfur dioxide emissions to GDP, completed investment in industrial pollution control, the Engel coefficient, and the urban–rural coordination degree, are processed by the range transformation method. The specific formula is as follows:

$$x_{ij}^{'} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}}$$

where x_{jmax} and x_{jmin} denote the maximum and minimum values of indicator j across all samples. Resulting $x'_{ji} \in [0,1]$, with smaller original values yielding larger transformed values.

For three moderate-direction indicators—foreign investment dependency ratio, CPI, and fiscal expenditure/GDP—we apply the absolute deviation method:

$$x_{ij}^{'} = -\left| x_{ij} - k_j \right|$$

where k_j denotes the optimal value of indicator j.

Step 2: Z-score standardization. Normalize all post-transformed indicators to eliminate unit effects:

$$z_{ij} = \frac{x_{ij}^{'} - \overline{x_j}}{s_j}$$

where $\bar{x}_j$ denotes the mean of the j indicator, S_j epresents the standard deviation, and z_{ij} refers to the standardized value.

(2) Principal Component Extraction and Scoring

If a second-level dimension comprises p underlying indicators, the data matrix is $z_{n \times p}$, where n is sample size.

Step 1: Compute correlation matrix R.

$$R = \frac{1}{n-1} Z^T Z$$

Step 2: Solve eigenvalue equation $|\lambda I\text{-}R|=0$ to obtain p non-negative eigenvalues $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_p$and corresponding unit eigenvectors u_1, u_2, ..., u_p.

Step 3: Determine number m of principal components, requiring cumulative variance contribution rate $\alpha \geq 85\%$:

$$\alpha = \frac{\sum_{n=1}^{m} \lambda_k}{\sum_{k=1}^{p} \lambda_k} \geq 0.85$$

Step 4: Compute principal component scores. The k-th principal component F_k is:

$$F_k = Zu_k = u_{k1}Z_1 + u_{k2}Z_2 + \cdots + u_{kp}Z_p$$

Step 5: Compute composite score S for the second-level dimension:

$$S = \sum_{k=1}^{m} \left(\frac{\lambda_k}{\sum_{k=1}^{m} \lambda_k} \cdot F_k \right)$$

Repeat this process for all six second-level dimensions to obtain annual composite scores for environmental improvement, economic development, opening-up, radiating and driving effects, business environment, and scientific and technological innovation.

3.2.2. AHP-Based Weight Determination for Second-Level Dimensions

AHP decomposes complex problems into hierarchical structures and determines relative importance via expert pairwise comparisons—suitable for multi-objective decision-making.

(1) Hierarchical Structure Model

Goal layer: FTZ sustainable development level (A);Criterion layer: six second-level dimensions—environmental improvement (B_1), economic development (B_2), opening-up (B_3), radiating and driving effects (B_4), business environment (B_5), scientific and technological innovation (B_6).

(2) Judgment Matrix Construction

Using Saaty's 1–9 scale, 15 domain experts conducted pairwise comparisons of dimension importance. The geometric mean of individual judgment matrices formed the final matrix $A = (a_{ij})_{6\times6}$, where a_{ij} indicates the relative importance of dimension i versus j ($a_{ij} > 0$, $a_{ij} = 1/a_{ji}$). See Table 7 for illustration.

Table 7. Judgment Matrix for Second-Level Dimensions.

	Environmental Optimization	**Economic Development**	**Opening-up**	**Radiation-driven Capacity**	**Business Environment**	**Scientific and Technological Innovation**
Environmental Optimization	1	1/5	1/7	1/3	1/5	1/3
Economic Development	5	1	3	5	3	3
Opening-up	7	1/3	1	5	3	5
Radiation-driven Capacity	3	1/5	1/5	1	1/3	1/3

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Business Environment	5	1/3	1/3	3	1	3
Scientific and Technological Innovation	3	1/3	1/5	3	1/3	1

(3) Weight Vector Calculation and Consistency Check

Step 1: calculate the eigenvectors. The sum-product method is adopted to compute the maximum eigenvalue λmax and its corresponding normalized eigenvector $W = (w_1, w_2, \ldots, w_6)^T$.The steps of the sum-product method are as follows: normalize each column of the judgment matrix, sum the elements by row, and then divide the result by the dimension number.

Step 2: Consistency check. Compute consistency index

$$CI = \frac{\lambda_{\max} - n}{n-1}, CR = \frac{CI}{RI}$$

where RI is the average random consistency index. If CR < 0.1, the matrix passes consistency validation. Here, λ_{max} = 6.5321, CI = 0.1064, CR = 0.0845 < 0.1 validation passed. Final weights appear in Table 8.

Table 8. Weights for Second-Level Dimensions in FTZ Sustainable Development Evaluation.

Indicators	Environmental Optimization	Economic Development	Opening-up	Radiation-driven Capacity	Business Environment	Scientific and Technological Innovation
Weights	0.04	0.37	0.29	0.06	0.15	0.09

3.2.3. Composite Sustainable Development Score Calculation

Linearly weight the PCA-derived annual dimension scores with AHP-determined weights w_k:

$$T_{it} = \sum_{k=1}^{6} w_k \cdot S_{it}$$

4. Analysis of Composite Sustainable Development Scores

4.1. Results of Sustainable Development Level Measurement

The measurement results of the sustainable development levels of 22 FTZs from 2013 to 2022 are shown in the Table 9.

Table 9. Sustainable Development Levels of 22 FTZs, 2013–2022.

Province	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Shanghai	0.35	0.38	0.41	0.42	0.45	0.48	0.49	0.51	0.55	0.58
Fujian			0.19	0.21	0.22	0.23	0.26	0.28	0.31	0.34
Guangdong			0.57	0.61	0.64	0.75	0.79	0.81	0.88	0.90
Tianjin			0.30	0.29	0.29	0.28	0.28	0.31	0.34	0.35

Henan					0.29	0.34	0.38	0.40	0.44	0.45
Hubei					0.29	0.32	0.34	0.35	0.39	0.42
Liaoning					0.23	0.24	0.26	0.26	0.29	0.30
Shaanxi					0.19	0.21	0.22	0.25	0.28	0.29
Sichuan					0.25	0.30	0.33	0.35	0.38	0.41
Zhejiang					0.43	0.47	0.51	0.53	0.58	0.63
Chongqing					0.21	0.25	0.26	0.28	0.30	0.32
Hainan						0.10	0.13	0.17	0.18	0.23
Guangxi							0.20	0.22	0.25	0.29
Hebei							0.31	0.33	0.34	0.36
Heilongjiang							0.16	0.20	0.22	0.23
Jiangsu							0.62	0.65	0.72	0.76
Shandong							0.44	0.48	0.56	0.60
Yunnan							0.13	0.18	0.19	0.20
Anhui								0.31	0.35	0.39
Beijing								0.53	0.54	0.59
Hunan								0.35	0.37	0.41
Xinjiang										0.22

Overall, since the establishment of free trade zones (FTZs), the comprehensive scores reflecting sustainable development levels in most regions have shown an upward trend. Taking Shanghai as an example, its score rose from 0.35 in 2013 to 0.58 in 2022, while Guangdong increased from 0.57 in 2015 to 0.90 in 2022. This indicates that FTZs across regions have achieved continuous development and progress over time, with policy measures and construction investment gradually yielding tangible outcomes. Nevertheless, the development level of the Tianjin FTZ experienced a decline followed by a recovery between 2015 and 2022. Its score stood at 0.30 in 2015 and dropped to 0.28 from 2016 to 2019, mainly due to a sharp deterioration in opening-up indicators. Specifically, the score of this dimension fell drastically from 0.31 in 2015 to −0.35 in 2018.

The export structure of the Tianjin FTZ is dominated by traditional manufactured goods with low added value and insufficient technological content. Faced with dual pressures from low-cost competition in Southeast Asia and the Middle East as well as increasingly stringent environmental regulations, its international competitiveness weakened. Meanwhile, as a pilot zone for institutional reform, some policy arrangements failed to generate immediate practical effects. Furthermore, traditional heavy industries account for a large proportion of Tianjin’s industrial structure. The transition toward high-end manufacturing and modern service industries brought short-term economic adjustments. The disjointed progress between emerging industry cultivation and traditional industrial upgrading led to sluggish growth in economic development and scientific and technological innovation indicators, further dragging down the overall comprehensive score.

After 2020, however, the Tianjin FTZ bottomed out and rebounded. Thanks to policy optimization and improved industrial layout, its score recovered to 0.31 and further increased to 0.35 in 2022, reflecting the gradual release of reform dividends. The environmental optimization indicator steadily improved from negative values to 0.24 in 2022, providing solid foundational support for high-quality development. The radiation-driven capacity improved markedly, rising from 0.53 in 2015 to 0.91 in 2022. This demonstrates that the Tianjin FTZ has strengthened its economic spillover effect and coordinated development with surrounding areas. Relying on the Beijing–Tianjin–Hebei coordinated development strategy, it has deepened resource linkage with Beijing and Hebei and enhanced regional influence.

The opening-up indicator also stopped falling and began to recover. Although still negative at −0.28 in 2022, it represented an improvement compared with −0.38 in 2019, suggesting that targeted adjustments such as foreign trade structure optimization and refined foreign investment guidance have achieved initial results. The business environment indicator gradually improved from −0.08 in 2015, driven by higher efficiency in government services and the implementation of institutional innovations, which effectively stimulated market vitality. In addition, the scientific and technological innovation indicator increased from −0.13 in 2015 to 0.38 in 2022. This improvement proves that greater innovation input and industrial upgrading have produced positive results, and the expansion of emerging industries has become a key driving force for the rise in comprehensive scores. In general, the Tianjin FTZ has achieved steady progress in policy improvement and industrial restructuring, supporting the continuous enhancement of its overall development capacity.

Growth rates varied substantially across different regions. Coastal FTZs in Shanghai, Guangdong, Zhejiang, Jiangsu and Shandong registered prominent growth momentum. Shanghai's comprehensive score increased from 0.35 in 2013 to 0.58 in 2022, Guangdong's score surged from 0.57 in 2015 to 0.90 in 2022, and Zhejiang's score rose from 0.43 in 2017 to 0.63 in 2022. Benefiting from long-term economic accumulation and early opening-up practices, coastal regions possess superior port endowments and mature trade systems. Their first-mover advantages in commodity trade and foreign investment attraction have jointly driven the rapid improvement of sustainable development performance.

Inland FTZs in Henan, Hubei, Sichuan and Shaanxi maintained steady yet moderate growth. Henan's score increased from 0.29 in 2017 to 0.45 in 2022, and Hubei's score climbed from 0.29 in 2017 to 0.42 in 2022. Supported by national strategies including the Rise of Central China and the Western Development Program, inland regions have actively undertaken industrial relocation. Even so, their weaker economic foundation and lower opening-up level compared with coastal areas restrict growth potential and result in moderate development momentum.

Border FTZs such as Yunnan, Heilongjiang and Guangxi recorded the slowest growth. Yunnan's score increased slightly from 0.13 in 2019 to 0.20 in 2022, and Heilongjiang's score rose from 0.16 in 2019 to 0.23 in 2022. Restricted by weak economic fundamentals, border regions boast geographical advantages in cross-border trade, yet their potential for cross-border economic cooperation and industrial integration remains underdeveloped. Constrained by multiple structural factors, these regions struggle to cultivate strong growth drivers, leading to slow progress in sustainable development.

4.2. Current Status Analysis

Ranking 2022 composite scores reveals stark disparities: Guangdong (0.90), Shanghai (0.58), Jiangsu (0.76) rank highest; Xinjiang (0.22), Yunnan (0.20) lowest (Table 10).

Table 10. Sustainable Development Levels of FTZs in 2022.

Region	Guangdong	Jiang su	Zhejiang	Shandong	Beijing	Shanghai	Henan	Hubei
Score	0.70	0.74	0.05	0.45	1.05	0.14	0.62	0.06

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Region	**Guangdong**	**Jiangsu**	**Zhejiang**	**Shandong**	**Beijing**	**Shanghai**	**Henan**	**Hubei**
Ranking	1	2	3	4	5	6	7	8
Region	Hunan	Sichuan	Anhui	Hebei	Tianjin	Fujian	Chongqing	
Score	0.10	0.24	0.71	0.42	0.24	0.13	0.59	
Ranking	9	10	11	12	13	14	15	
Region	Liaoning	Shaanxi	Guangxi	Heilongjiang	Hainan	Xinjiang	Yunnan	
Score	-0.12	0.31	0.03	-0.29	0.35	0.35	0.06	
Ranking	16	17	18	19	20	21	22	

In 2022, Guangdong achieved an overall comprehensive score of 0.9, ranking first nationwide. An analysis of its sub-indicators shows that it secured the top position in opening-up, business environment, and scientific and technological innovation. Its economic development score reached 0.92, ranking second. Such multi-dimensional coordinated advantages enabled Guangdong to take a substantial lead in the overall evaluation. In terms of opening-up, the Guangdong FTZ covers Qianhai, Nansha, Hengqin and other sub-zones. It takes the lead in piloting reforms on investment facilitation and trade liberalization, attracting massive foreign capital inflows and extensive global trade connections. In terms of the business environment, Guangdong has continuously advanced the reform of streamlining administration, delegating power, improving regulation, and optimizing services, and built a digital government service system. Coupled with stringent intellectual property protection and a sound market competition mechanism, it has fostered a favorable ecosystem for enterprise development and innovation. Consequently, its business environment score reached 2.37, ranking first across all regions. In the field of scientific and technological innovation, Guangdong is home to world-leading technology enterprises such as Huawei and Tencent, forming robust innovative industrial clusters. Meanwhile, it promotes in-depth integration of industry, university and research. Driven by a strong innovation atmosphere and solid innovative strength, Guangdong scored 0.9 in scientific and technological innovation and claimed the top spot, injecting core momentum into high-quality and sustainable economic development. Its economic development level ranks only second to Jiangsu, supported by a solid manufacturing foundation. Industries including electronic information, household appliances and automobiles feature large scale and strong competitiveness. The combined driving forces of an export-oriented economy and innovation have sustained steady and robust economic growth.

Ranking second in the overall evaluation, Jiangsu also boasts coordinated strengths in multiple core indicators. It secured the first place in economic development with a score of 1.25, the second in environmental optimization at 0.74, and the second in business environment with 1.90, only below Guangdong. These achievements stem from its long-term adherence to a multi-dimensional coordinated development strategy. In terms of economic development, Jiangsu demonstrates outstanding comprehensive strength. As a major manufacturing province in China, it has cultivated advanced manufacturing clusters represented by the electronic information industry with prominent industrial agglomeration effects. In addition, Jiangsu actively promotes industrial transformation and upgrading, vigorously develops the digital economy and intelligent manufacturing, and achieves parallel progress between traditional and emerging industries. This provides lasting impetus for sustainable economic growth and underpins its leading position in economic development. In the dimension of environmental optimization, Jiangsu has advanced major ecological projects such as the Yangtze River ecological protection and comprehensive water environment improvement in the

Taihu Lake Basin. It has strengthened regulation on high-pollution and high-energy-consumption enterprises, and widely promoted clean energy and green production modes, striking a balance between economic growth and ecological conservation. With a score of 0.74, it ranks second in environmental optimization, next only to Beijing. For business environment construction, Jiangsu deepens institutional reform and innovation continuously. It optimizes government service procedures and realizes one-stop online administrative services via the Jiangsu Government Service Network, greatly improving administrative efficiency for enterprises. Furthermore, it improves the policy support system, offering all-round support for enterprises in talent introduction, technological innovation, fiscal and tax incentives. It also enhances intellectual property protection and market supervision to build a fair competitive market. Thanks to these measures, Jiangsu's business environment score reached 1.90, steadily ranking second nationwide.

These competitive advantages are not isolated but mutually reinforcing to form a virtuous cycle. Higher levels of opening-up bring sufficient capital, advanced technologies and mature management experience, optimizing the business environment and the allocation of innovative resources. A sound business environment attracts high-quality enterprises and talents, further stimulating innovative vitality. Scientific and technological innovation, in turn, drives industrial upgrading, improves economic development quality and elevates the level of opening-up. Jointly empowered by multi-dimensional coordination, Guangdong and Jiangsu occupy the top two positions in the overall ranking, serving as benchmarks for high-quality regional development.

As megacities, Beijing and Shanghai are characterized by prominent unilateral advantages and insufficient systematic coordination. Shanghai registers the highest score of 1.21 in radiation-driven capacity and ranks second in scientific and technological innovation with a score of 1.61. These two core indicators reflect its strong comprehensive capacity, constituting the core support for its overall competitiveness. As one of China's most economically dynamic cities, Shanghai's radiation-driven effects continue to radiate outward through a development model featuring central leadership and regional linkage. In scientific and technological innovation, Shanghai functions as a national key science and innovation hub. The Zhangjiang Science City houses major scientific facilities including the Shanghai Synchrotron Radiation Facility and the National Center for Protein Sciences. Universities and research institutions such as Fudan University and Shanghai Jiao Tong University have built an innovation ecosystem with deep industry-university-research integration. Nevertheless, Shanghai scores only 0.14 in environmental optimization with a low overall ranking, which stands out as a prominent shortcoming. This is closely related to its urban development stage. Limited land resources lead to imbalanced green space distribution, with the per capita park green area of merely 8.8 square meters, lower than the average level of major Chinese cities. Despite continuous progress in building a zero-waste city in recent years, the transitional pains of industrial restructuring, together with the tight balance between population, resources and environment, have resulted in slower improvement of environmental indicators compared with economic and technological progress. This pattern of prominent strengths and obvious weaknesses is directly reflected in its overall ranking. Although outstanding radiation-driven capacity and scientific and technological innovation consolidate its strategic advantages, the backward performance in environmental optimization undermines its balanced development.

Beijing achieves the nation's highest environmental optimization score of 1.05 and a high ranking in scientific and technological innovation at 1.86, second only to Guangdong and Jiangsu. These two indicators represent its top-tier national competitiveness and underpin urban comprehensive strength. However, it scores −0.2 in opening-up with a poor ranking, forming a major shortcoming that restrains its overall competitiveness. Leading the country in environmental optimization, Beijing provides valuable experience for the green transformation of other cities. As a megacity, it once faced severe challenges such as excessive PM2.5 concentration, water shortage and urban heat island effects. Through the implementation of three major ecological defense campaigns targeting air, water and soil pollution, Beijing has achieved historic improvements in ecological quality. Scientific and technological innovation serves as another world-class strength of Beijing, consolidating its status as a vital node in the global innovation network. Relying on the "Three Science Cities and One Pilot Area" innovation layout, Beijing has established a complete industrial chain covering original innovation, technological transformation and industrial application. In sharp contrast, Beijing's opening-up indicator stood at −0.2, ranking 8th in 2022. In terms of scale expansion, although the Beijing FTZ has lowered the income access threshold for member enterprises, its institutional arrangement remains rigid compared with the Shanghai FTZ, which adopts unrestricted access and customized credit limits based on comprehensive bank evaluation. In the emerging cross-border integrated capital pool business, Beijing only supports domestic accounts for overseas institutions with complicated bank account opening procedures, lacking the functionality and flexibility of the free trade account system piloted in Hainan and Shanghai. Compared with Shanghai and Guangdong, Beijing still has substantial room for improvement in opening-up. It is necessary to further break institutional barriers, strengthen the agglomeration of global high-end factors, promote innovation and high-quality development through opening-up, and realize coordinated progress between advantageous fields and weak links.

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

5. Conclusions and Policy Implications

5.1. Conclusions

Based on relevant data of China's 22 Free Trade Zones (FTZs) from 2013 to 2022, this paper conducts a comprehensive evaluation of their sustainable development levels from six dimensions: environmental optimization, economic development, opening-up degree, radiation-driven capacity, business environment, and scientific and technological innovation capability. The research findings are as follows:

(1) The comprehensive evaluation results reveal that the overall composite scores of sustainable development in most FTZs show an upward trend, while the growth rates differ significantly across regions. Coastal FTZs including Shanghai, Guangdong, Zhejiang, Jiangsu and Shandong maintain a strong growth momentum; inland FTZs such as Henan, Hubei, Sichuan and Shaanxi achieve steady yet moderate growth; and border FTZs represented by Yunnan, Heilongjiang and Guangxi register a relatively modest growth range.

(2)Further comparison indicates that the comprehensive scores of the 22 FTZs in 2022 present an obvious gradient distribution and prominent regional development imbalance. There exists a notable gap between the top-ranked regions of Guangdong, Jiangsu and Zhejiang and the bottom-ranked ones including Yunnan, Xinjiang and Heilongjiang.

5.2. Policy Recommendations

Given regional divergence and uneven development, targeted measures should align with strategic positioning and functional orientation:

First, adopt region-specific empowerment: Support coastal FTZs (Shanghai, Guangdong, Zhejiang) to pioneer institutional openness, deepen alignment with high-standard international rules via port advantages, and amplify "growth pole" spillovers. For inland FTZs (Henan, Hubei, Sichuan, Shaanxi), prioritize logistics corridor development ("land-sea linkage, east-west mutual support") and integrate equipment manufacturing/electronics with trade to strengthen endogenous growth. For border FTZs (Yunnan, Heilongjiang, Xinjiang), tailor policies to geographic advantages—streamline border customs clearance, establish cross-border industrial funds, and foster specialty sectors (cross-border agriculture, energy equipment) to narrow gaps.

Second, promote cross-regional sharing of best practices: Compile replicable institutional innovations and disseminate them via national FTZ collaboration platforms; pair leading and lagging FTZs—e.g., Shanghai-Anhui-Jiangxi "Yangtze River Delta FTZ Development Belt"; Guangdong-

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Guangxi-Yunnan cross-border innovation platforms—to enable "strong-leading-weak, excellence-compensating-deficiency." Encourage each FTZ to consolidate strengths while addressing weaknesses—advancing coordinated progress across environmental, economic, and innovation dimensions.

Third, establish dynamic monitoring and adjustment mechanisms: Regularly track composite and dimensional scores, adapt classification-based support policies to evolving global and domestic conditions, encourage differentiated experimentation, avoid homogenized competition, ensure development pathways precisely match strategic mandates, and sustainably unlock institutional innovation dividends.

References

1. Jia, C., & Hua, Y. (2024). Do China's Pilot Free Trade Zones Suppress Environmental Pollution? Empirical Evidence from 281 Chinese Cities. China Environmental Management, 16(3), 82–91.
2. Xiao, L., & Zhang, Y. (2025). Effects of Pilot Free Trade Zones on Pollution Reduction and Carbon Emission Mitigation. World Regional Geography Research, 34(2), 98–113.
3. Qiu, D., Cao, A., & Gan, J. (2022). Does Establishing Free Trade Zones Promote Economic Growth Differently Across Regions? A Quasi-Natural Experiment. Investment Research, 41(11), 65–81.
4. Zhang, M., & Li, F. (2022). Can the Establishment of Free Trade Zones Promote High-Quality Regional Economic Development? Evidence from Central and Western China. In West Forum on Economy and Management (Vol. 33, No. 6, pp. 57–68).
5. Bao, T., Dai, Y., Feng, Y., et al. (2023). Trade Liberalisation and Trade and Capital Flows: Evidence from China's Pilot Free Trade Zones. The World Economy, 46(5), 1408–1422.
6. Ye, G., Huang, Y., & Wei, W. (2024). Promotive Effects and Pathways of Free Trade Zone Construction on Coastal Port Logistics Efficiency. Business Economics Research, (23), 93–96.
7. Wang, Y., Shi, M., & Zhang, Y. (2023). Did Free Trade Zone Establishment Promote High-Quality Urban Economic Development? A Quasi-Natural Experiment Based on 268 Chinese Cities. Contemporary Economic Research, (6), 102–118.
8. Mahmood, H. (2023). Trade, FDI, and CO_2 Emissions Nexus in Latin America: Spatial Analysis Testing Pollution Haven and EKC Hypotheses. Environmental Science and Pollution Research, 30(6), 14439–14454.
9. Zhufu, H., Liu, J., & Luo, C. (2023). Optimizing the Business Environment and Radiating Effects in the Yellow River Basin Free Trade Zone Alliance. Industrial Technology Economics, 42(2), 154–160.
10. Wang, Y., & Kong, Q. (2024). The Impact of Free Trade Zones on Corporate Sustainability Performance: An Empirical Examination from the Dual Perspectives of Financial and Environmental Performance. Sustainability, 16(21), 9376.
11. Su, Z., Gong, S., & Li, Z. (2025). Spatial Network Structure Analysis of Provincial Business Environments in China: A Perspective from Free Trade Zones. Journal of Dalian University of Technology (Social Sciences Edition), 46(1), 26–36.
12. Wei, W., Zhu, D., & Wang, X. (2024). Can FTZ Policies Enhance Urban Innovation Capacity? Evidence from Chinese City Panel Data (2010–2019). Science of Science and Management of S&T, 45(6), 71–88.
13. Xu, S., Shen, R., Zhang, Y., et al. (2024). Fostering Regional Innovation Efficiency Through Pilot Free Trade Zones: Evidence from China. Economic Analysis and Policy, 81, 356–367.
14. Tian, B., & Li, W. (2015). Establishment and Evaluation of Inland Free Trade Zones: A Case Study of Wuhan. International Business Research, 36(4), 47–55.
15. Liu, J., & Yang, Z. (2016). Research on Comprehensive Performance Evaluation Index System for China's Pilot Free Trade Zones. Asia-Pacific Economic Review, (3), 113–121.
16. Zhang, S. (2017). Evaluation Research on Influencing Factors of FTZ Comprehensive Development Level. Regional Economic Review, (6), 112–120.
17. Gao, Z., Liao, M., & Jin, H. (2018). Research on Influencing Factors of Inland Free Trade Zone Development. Journal of Southwest Jiaotong University (Social Sciences Edition), 19(2), 100–106.
18. Xu, M., Dong, D., & Chang, B. (2020). Research on Evaluation of China's FTZ Development Level. Statistics and Information Forum, 35(6), 105–114.

doi:10.20944/preprints202604.2075.v1

19. Zhu, Y. (2021). Comparative Study on Evaluation of Domestic and International Free Trade Zones. Modern Commerce, (28), 9–11.
20. Zuo, S. (2021). Research on High-Quality Development of China's Pilot Free Trade Zones from the Perspective of Comprehensive Advantages (Doctoral dissertation, Guangxi University).
21. Shi, J. (2024). Evaluation and Influencing Factors of High-Quality Development in Heilongjiang FTZ (Master's thesis, Harbin University of Commerce).
22. Gao, Z., & Ke, H. (2020). Comparative Study on High-Quality Economic Development Levels in China's Border Provinces. Economic 纵横, (2), 23–35+2.
23. Fan, A., Pan, H., & Wang, X. (2024). Construction and Measurement of Evaluation Index System for High-Quality Development of Port Economies: Empirical Research on Yunnan Province. Journal of Yunnan Minzu University (Philosophy and Social Sciences Edition), 41(2), 115–128.
24. Yu, L., & Hu, J. (2023). Effects of the Digital Economy on High-Quality Economic Development in Provinces with FTZs. Modern Economic Research, (4), 1–14.
25. Cao, J., Zhou, X., Wang, S., et al. (2024). Mechanisms of the Digital Economy's Impact on High-Quality Urban Economic Development in Underdeveloped Regions: Mediating Role of Technological Innovation. Science & Technology Management Research, 44(10), 84–93.
26. Sun, Y., Xu, A., & Zhu, J. (2024). Analysis of Regional Trade Facilitation Levels and Disparities in China: A Case Study of Six Core Economic Circles. Business Economics Research, (9), 176–179.
27. Shi, W. (2018). Assessment of Trade Facilitation Progress in Western China and Its Economic Growth Effects. Reform, (7), 127–136.
28. Gao, Z., & Song, Y. (2018). Research on Trade Facilitation Level in China-Pakistan Free Trade Zone. Journal of Xinjiang University (Philosophy & Humanities Edition), 46(4), 52–60.
29. Hong, J., Wu, Z., & Zheng, Y. (2022). Practice and Reflections on Advancing High-Level Trade and Investment Liberalization and Facilitation in China. International Trade, (7), 4–12.