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Structural Equilibrium of Corporate ESG and Linkage with Economic System: A Case Study of SK Hynix

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Abstract: ESG (Environmental, Social, and Governance) has gradually evolved from a concept to a global consensus, and ESG research has also moved from policy exploration and macroeconomics to micro governance at the corporate level. This study takes SK Hynix as a case study and proposes the concept of "structural equilibrium of ESG". It integrates entropy method, coupling coordination index and grey correlation degree to track 17 years of time series data and quantitatively characterize the dynamic interaction and collaborative evolution process between ESG subsystems. The research conclusion is as follows: Firstly, the comprehensive evaluation values of the four subsystems of economy and ESG generally maintain an upward trend, Compared with ESG, the evaluation value of the economy shows a trend of lagging behind first and then leading. The input-output of ESG does not increase synchronously, but presents a phased emphasis. Secondly, the coupling degree of SK Hynix's four subsystems advances and retreats synchronously, and most of the time they are in a high-level coupling stage. When encountering a development crisis, ESG and economic benefits may exhibit an antagonistic development state, which may result in "crowding out effect" and "leverage effect". The coupling coordination index between ESG subsystems and the economy is gradually increasing, but the level of collaborative development is in a state of mild imbalance to near imbalance. Finally, the overall grey correlation coefficient between corporate ESG and the economy is on a downward trend, and the increase in ESG is smaller than that of the economic system, forming a scissors gap. The importance of the environment and society in corporate operations is far less than that of governance, and social performance may be the most external reference for business operations. This study provides a new perspective for understanding the multidimensional conflicts and dynamic synergies of ESG management, and provides dynamic decision-making references for enterprises to optimize ESG resource allocation and governments to improve differentiated policies.

Keywords: ESG; Economic system; structural equilibrium; coupling coordination index; grey correlation degree

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1 Introduction

The concept of ESG originated from responsible investment and social responsibility (ISO 26000), which is a comprehensive evaluation of enterprises from the perspectives of environment, society, and governance. It is an important component of non-financial information disclosure by listed companies to the capital market, and an important basis for investors to evaluate the non-financial risks and sustainable development potential of enterprises. It can avoid operational risks for enterprises, improve the ability to resist systemic risks, and thus achieve higher long-term investment returns. The complete concept was first proposed in 2004, when Kofi Annan, then the Secretary General of the United Nations, invited the CEOs of dozens of top investment institutions from around the world to participate in the ESG initiative jointly launched by the United Nations financial organization and the Swiss government. He also released the "Who Cares Wins Connecting Financial Markets to a Changing World" report, proposing recommendations to stakeholders around "investment markets + sustainable society" to promote the integration of environmental, social, and governance factors into development. In 2006, the United Nations Principles for Responsible Investment (UNPRI) was officially established, proposing the ESG framework. In the same year, the Goldman Sachs Environmental Policy: 2006 Year End Report was released, officially listing the three terms ESG together. The concept of ESG has been officially proposed for 20 years since 2004. ESG has been explored for many years from its conceptual connotation to the supporting ESG investment index, ESG report, ESG information disclosure, ESG system capacity building, and ESG management system certification. The development of ESG has also undergone an evolution from concept proposal to practical implementation, from voluntary initiative to global consensus. However, there is a clear differentiation in the current global ESG development, facing unprecedented multiple challenges. On the one hand, the anti ESG movement is intensifying in the United States, causing significant setbacks to ESG; On the other hand, Europe and Asia are relatively confident in promoting ESG development (Xiao, 2024). ESG research has also shifted from policy exploration and macroeconomic analysis to micro governance at the corporate level, making it increasingly important to delve into the ESG implementation models of enterprises.

In ESG evaluation, the three aspects of environment, society, and governance are inseparable, and these three aspects are interrelated and influence each other, as well as the performance of the enterprise. Existing ESG research focuses on a single dimension (such as environmental performance or governance level) or studies the relationship between the environment, society, and governance as a whole and the external environment, with less attention paid to the internal relationships between the three subsystems, as well as their synergy and asynchrony. The nonlinear process of this structure is a process from disorder to order, gradually moving towards rational understanding and objective evaluation. The important research proposition of this article is what method should be used to deeply evaluate the interrelationships between various element structures. Structuralism originated from linguistics and later expanded to social sciences. It is an analytical paradigm that emphasizes "systemic integrity" and "internal relationships". Its core lies in the fact that the meaning and function of a system are determined by the structural relationships of its internal elements. It is very suitable for complex system analysis of nonlinear relationships, long-term dynamic evolution research, conflicts and equilibria within the system, and other research scenarios.

This study proposes the following research questions:

Q1: What is the collaborative relationship between the ESG subsystems of the enterprise in terms of structure.

Q2: How is the ESG subsystem of a company constrained by its economic situation.

Q3: How corporate ESG and its relationship with the economic system dynamically evolve.

Therefore, this study proposes the concept of "structural equilibrium", starting from a structuralist perspective, viewing ESG as a complex system composed of interdependence among environment, society, and governance. Through the fluctuation of ESG indicators, it reveals the underlying structural contradictions and explains how the system achieves new dynamic equilibrium through internal dynamic evolution. The study adopts a perspective of in-depth case exploration, selecting SK Hynix, a globally leading semiconductor solution provider, as a typical case. The mining of long-term data (2007-2023) provides a highly reliable empirical basis for the study and lays the foundation for subsequent cross industry comparative research. This study integrates mathematical and statistical methods such as entropy method (measuring system complexity), coupling coordination index (evaluating subsystem synergy), and grey relational analysis (analyzing dynamic relationships between variables) to reveal the synergistic evolution trend of ESG subsystems and economic indicators through time series data. Research can to some extent deepen the structural equilibrium theory of ESG management. This multi model empirical analysis provides methodological examples for complex system analysis, and visual analysis also provides dynamic decision-making basis for policy formulation and corporate strategic adjustment.

2 Literature Review

2.1 Progress in Corporate ESG Research

Although the concept of ESG has been proposed for 20 years, the number of international studies has only begun to increase sharply since 2017. In recent years, related research has mainly focused on the relationship between ESG and economic performance, specific industry ESG practices, ESG policy regulation and evaluation standards, and AI technology empowering ESG from multiple perspectives. From a developmental perspective, Xiao (2024) proposed a four stage evolution model for ESG (exploration period, rise period, rapid growth period, and normative development period), which presents the evolutionary logic and characteristics of progressive institutional arrangements, compatible international rules, diverse subject practice s, and self-organizing ecosystems. ESG is gradually transitioning from a "shareholder first" paradigm to a "stakeholder balance" paradigm (Zheng & Wang, 2024). As ESG becomes an indispensable part of corporate strategy, it is increasingly receiving attention from investment institutions, business leaders, and stakeholders (Cai & Hao, 2025), and employees' views on ESG standards are also reflected in their work environment (Barbosa et al., 2025). ESG not only expands responsible green investment practices (Pedersen et al., 2021), but also integrates into corporate strategies and governance frameworks, becoming a continuous driving force for companies to fulfill social responsibility, increase transparency, and improve governance (Gil lan et al., 2021). The governance dimension plays a key role in ESG performance, and high ESG rated companies typically have more comprehensive board supervision mechanisms. Optimizing governance mechanisms such as the proportion of independent directors can enhance risk management capabilities (Eccles et al., 2014). Cai and Hao (2025) used instrumental variable regression and GMM methods to address potential endogeneity issues and found that the ability to integrate ESG into corporate strategy is still limited. In terms of disclosure willingness, under mandatory d isclosure, the quality of ESG disclosure is higher, and the environmental, social, and government performance of companies that disclose ESG reports has also improved. Mandatory ESG disclosure has information advantages over voluntary disclosure, as it alleviates information asymmetry and ultimately reduces earnings management by increasing transparency of specific accounting items (Cui et al., 2025). Yoo and Managi (2022) used two different ratings and over one million sample surveys to conclude that disclosure is more important for profit, while action is more important in Tobin Q and IVA scores.

The research focuses on the impact of ESG investment on financial performance, risk management, long-term competitiveness, and other aspects of corporate economic performance. Friede et al. (2015) conducted a meta-analysis of over 2000 empirical studies and found that approximately 90% of the research supported a positive correlation between ESG performance and financial performance, particularly in the long-term perspective where investments in environmental governance (E) and social responsibility (S) had a significant impact on profitability. From a macro perspective, Işık et al. (2024) developed the ECON-ESG quadruple, adding the economic (ECON) dimension to the classic ESG triple, and explored the crucial impact of ECON-ESG factors on the load capacity coefficient (LCF) of the G7. Liang and Renneboog (2020) compared data from 40 countries and found that ESG premiums are higher in emerging markets, with policy incentives such as green credit in China being key moderating variables. Some scholars are focusing on regional ESG practices, and there has been a significant increase in papers using China as a case study. Wang et al. (2025) established an ESG disclosure quality evaluation system for the Chinese energy industry and examined the significant positive impact of ESG disclosure quality on financial performance from 2015 to 2021. Financing costs, technological innovation, and inefficient investments have a mediating effect between the two. Cai and Hao (2025) evaluates the impact of ESG performance on the export performance of

Chinese listed companies from 2009 to 2015. Some scholars have focused on specific industries and enterprises, and the differences in ESG paths and policy driving effects among different industries (such as finance, technology, forestry). Pedersen et al. (2021) proposed the "ESG Efficient Frontier" theory, quantifying the balance point between ESG investment and financial returns. Companies with excellent ESG performance have higher risk adjusted returns in long-term investments. Khan et al. (2016) proposed the theory of "substantive issues" to demonstrate that differentiated ESG priorities in industries (such as energy industry focusing on emissions reduction and semiconductor industry focusing on environmental technology innovation) can enhance stock prices and capital efficiency. Lee et al. (2023) takes SK Hynix as an example and believes that green technology innovation, such as low-carbon chip processes, drives industry competitiveness. Barbosa et al. (2025) used PLS-SEM, PROMETHEE-ROC, and FIMIX-PLS methods to empirically investigate the impact of employees' views on ESG on the sustainable development performance of the Brazilian electrical industry.

Along with the impact of ESG on economic benefits, the factors that affect ESG have also become a research direction. Digitization and greenization are the current industry directions. Fang et al. (2023) took Chinese listed companies as an example and found that digitalization significantly improved ESG scores. Digitization enables companies to reduce agency costs and improve governance (G) scores, which helps companies increase goodwill and further improve social (S) scores. Green manufacturing is widely regarded as an important way for companies to gain sustainable competitive advantages. Zeng et al. (2024) used a quasi natural experimental method, enhancing green innovation capabilities and reducing financing constraints are two key channels for improving ESG performance through green manufacturing. In terms of corporate development policies, Yang (2025) incorporates ESG into the production decision-making model and, from the perspective of collaborative governance, indicates that the existence of shared ownership reduces the uncertainty of corporate ESG factors. The collaborative governance effect can alleviate fluctuations in ESG performance and reduce the uncertainty of overall ESG ratin gs. In the context of comprehensive economic transformation and technological change, ESG, as an important strategy for resource acquisition and sustainable development, has an inherent inverted U-shaped connection with the acquisition of supply chain financing (Xin et al., 2025). The uncertainty of environmental information and market competition also have a significant impact on corporate ESG. Shi et al. (2025) used sample data from non-financial listed companies on the Chinese A-share market from 2011 to 2022 and found that the uncertainty of environmental information hinders corporate ESG performance, with a more pronounced impact on non-state-owned enterprises and significant differences among companies in different life cycles. Market competition has improved the ESG performance of growth and mature enterprises, and company size is a positive moderating factor (Sun et al., 2025). From an external perspective, research has explored the impact of climate risk on the financial risk management framework for ESG integration (Drempetic et al., 2024).

Technology empowering ESG research has become a new feature, and artificial intelligence (AI) has become a powerful external promoter of sustainable business practices, with significant potential in strengthening corporate ESG governance (Zhou, 2025), with breakthroughs in research methods and themes. Simon's (1995) early research defined AI as "empirical science", emphasizing its ability to drive decision-making through data. Jiao's (2024) empirical research shows that AI technology can significantly enhance the environmental management capabilities of enterprises by optimizing energy efficiency and carbon emission monitoring, while reducing compliance risks. Pedersen et al. (2021) believes that when quantifying the balance point between ESG investment and financial returns, AI technology can enhance the operability of ESG strategies through data integration and predictive models in this process. Zhou et al. (2025) conducted a natural experiment based on the China National Artificial Intelligence Experimental Zone and applied the staggered double difference method. Through panel data of 1418 A-share listed companies in China from 2011 to 2022, it was found that artificial intelligence significantly improved ESG performance. However, at the same time, the unpredictability of AI may lead to technological stress (Issa, et al., 2024), and data fragmentation and algorithm transparency are the main challenges (Xiao, 2024).

Based on the current summary of ESG research, the grand narrative about ESG remains the focus, and economic methods are the mainstream direction. From a comprehensive assessment of multiple countries and regions in an international context, or focusing on a particular country or industry based on data factors, it has gradually shifted from macroeconomic to micro level corporate governance. It is becoming increasingly important to explore ESG logic from a micro level corporate perspective and delve deeper into it. This study emphasizes the structural tension and dynamic evolution within the system, revealing the nonlinear relationship and structural contradictions between the ESG subsystem and the economic system. It is a breakthrough from a holistic perspective and can provide a new perspective for understanding the multidimensional conflicts and synergies in ESG management (Holling, 2001).

2.2 Construction of ESG evaluation system

The quantitative ESG indicator system provides a quantitative and comparable way for companies to evaluate and report their performance in environmental, social, and governance aspects through specific data. However, the construction of ESG indicators, optimization of rating methods, and transparency and comparability of data have always been the focus of research. Berg et al. (2022) analyzed and criticized data from six mainstream ESG rating agencies (such as MSCI and KLD), stating that significant rating discrepancies were caused by differences in indicator weights, insufficient data transparency, and source differences. He called for the establishment of a standardized framework. There have been many industries and studies that have made some improvements, and Mian et al. (2024) has developed a three-stage method for ESG standards, which includes a comprehensive review and a research survey involving 62 experts. The conclusion is that the environment is about 5-14% more important than social and governance components. Design, service life, and material sources are relatively more important than project types by about 14-20%, while risks related to water and air pollution are about 34-38% more important than solid waste. Wang et al. (2023) emphasized the importance of industry adaptation models for ESG ratings and proposed a three-dimensional indicator of "technology resources governance" for the semiconductor industry, such as unit chip carbon emissions, supply chain responsibility coverage, and board ESG supervision intensity. Vijaya et al. (2025) uses Fuzzy DEMATEL and Fuzzy TOPSIS methods to explore the priorities and causal relationships of key performance indicators (KPIs) for ESG in the automotive industry, and proposes that among the 17 identified factors, corporate governance, air emissions, and sustainable product development are the primary tasks that affect improving ESG performance. Yang et al. (2025) constructed the SASB ESG score based on the guidelines of the Sustainable Development Accounting Standards Board (SASB). Covachev et al. (2025) believes that carbon and ESG are subordinate to other factors and are a linear combination of systemic risk factors.

Based on the framework of the International Organization for Standardization, such as the "substantive issues" dimension proposed by the Sustainable Development Accounting Standards Board (SASB) and the requirements of the Climate Related Financial Disclosure Working Group (TCFD), combined with South Korea's national policy requirements and initiatives, adopting the principles of convenience and scientificity, SK Hynix ESG evaluation dimensions and 34 evaluation indicators have been established. Economics (Ec) generally evaluates comprehensively from aspects such as assets, returns, and costs. Environmental (E) mainly measures the ecological impact and resource utilization of business operations, and is divided into three aspects: environmental investment, energy and raw material utilization, and environmental impact. Social (S) typically reflects a company's performance in terms of labor conditions, community impact, and social responsibility, including four levels: employees, community, consumers, and collaborative companies. Governance (G) represents the management structure, practices, and transparency of a company through quantitative statistics, which helps to understand the quality of governance and the responsibility of management to investors and other stakeholders. It is divided into several levels: governance structure, shareholder rights, labor relations, ethical risks, and compliance/transparency.

Table 1. Specific Dimensions and Indicators of Economic and ESG Subsystems

category	dimension	measurement indicator	measurement unit of indicator	Weight
Economic (Ec)	property	total assets	billion KRW	0.333
	profit	total sales	billion KRW	0.202
		operating profit	billion KRW	0.141
		net profit	billion KRW	0.088
	representative fees	research and development expenses	100 million KRW	0.236

Environmental (E)	environmental investment	SHE investment	100 million KRW	0.070
	environmental consumption	total energy consumption	Gigajoules (GJ)	0.128
		total consumption of raw materials	million KRW	0.109
		proportion of reused raw materials	%	0.145
		total water consumption	1000 m³	0.084
		water recycling rate	%	0.055
	environmental impact	greenhouse gas emissions	tCO_2eq	0.078
		air pollutant emissions	Ton (t)	0.159
		total amount of waste	Ton (t)	0.085
		waste recycling rate	%	0.027
		waste water discharge volume	m³	0.060
Social (S)	talent development	total number of employees	person	0.113
		employee diversity (proportion of female and minority employees, etc.)	%	0.085
		employee turnover rate (turnover rate)	%	0.140
		employee health and safety (work injury rate)	%	0.138
		employee training hours	hour	0.117
	community value	charitable donation amount	100 million KRW	0.150
		employee volunteer service hours	hour	0.065
	Consumer (product liability)	product satisfaction	5-point scale	0.045
	collaborative company (supply chain management)	number of cooperative enterprises	piece	0.149
Governance (G)	governance	proportion of external directors	%	0.060
		proportion of female managers	%	0.143
		Shareholding ratio of major shareholders	%	0.035
		shareholder voting ratio	%	0.086
	industrial relations	management compensation	million KRW	0.203
		salary ratio (the ratio of average employee salary to CEO)	times	0.222
	ethical risk	number of reports	piece	0.121
	compliant operation/ transparency	timeliness of information disclosure (proportion of timely release of annual financial reports)	%	0.001
		third party rating agency rating	hundred mark	0.129

3 Research Methods and Data Sources

3.1 Research Methods

3.1.1 Determination of indicator weights using entropy method

In information theory, entropy is a measure of the degree of chaos or disorder in a system. The larger the entropy value of an indicator, the smaller the variability index, and the smaller the weight of the indicator. The entropy method is used to calculate the entropy value of indicators and determine their weights based on the overall impact of changes in the numerical values of each indicator when dealing with multi indicator weighting problems. It can avoid the influence of subjective factors and improve the objectivity and accuracy of evaluation results.

(1) Standardize the original data set, eliminate dimensional differences in each indicator, and compress the values of each indicator within the range of [0-1], usually using range normalization method. The original value is X_{ij} (i=1, 2, 3... m, j=1, 2, 3... n), and u_{ij} is the processed data for the j-th indicator of the i-th scheme.

$$u_{ij} = \begin{cases} (x_{ij} - \min(x_{ij}))/\left(\max(x_{ij}) - \min(x_{ij})\right) + 0.01, u_{ij} \text{ has a positive effect} \\ (\max(x_{ij}) - x_{ij})/\left(\max(x_{ij}) - \min(x_{ij})\right) + 0.01, u_{ij} \text{ has a negative effect} \end{cases}$$

(2) Quantify the equivalence of each indicator, calculate the proportion P_{ij} of the i-th scheme indicator value under the j-th indicator, and realize the construction of the judgment matrix $X=\{x_{ij}\}_{m\times n}$ Normalize x n to obtain the standard matrix $P=\{P_{ij}\}_{m\times n}$.

$$P_{ij} = u_{ij} / \sum_{i=1}^{m} u_{ij}$$

(3) Calculate the entropy value of the j-th indicator, in the following formula, K=1/lnm, ln is the natural logarithm, $0 \leq E_j \leq 1$.

$$E_j = -K \sum_{i=1}^{m} P_{ij} \ln P_{ij}$$

(4) For a given j, the larger the difference in the indicator values between the different schemes of X_{ij}, the smaller E_j, and the greater the impact of this indicator on the scheme. So, defining the coefficient of difference D_j for the j-th indicator, $D_j = 1 - E_j$. Therefore, by determining the information weight w_j of the j-th indicator, a reasonable weight coefficient vector (w_1, w_2,... w_n) for each indicator can be obtained.

$$w_j = D_j / \sum_{j=1}^{n} D_j$$

3.1.2 Coupling Coordination Index Model

Contemporary collaborators and systems science both believe that each element plays an independent role, and the structural relationships between elements play a more important role than the elements themselves. The key to the mechanism of the system's transition from disorder to order lies in the synergistic effect between the internal order parameters of the system, which affects the characteristics and laws of the system's phase transition. The coupling coordination index is a measure that reflects this synergistic effect (Wang et al., 2020).

(1) Coupling degree calculation is used to preliminarily illustrate the mutual influence between various systems. C_n represents the coupling degree between n subsystems, and the larger the value of C, the smaller the degree of dispersion between subsystems, and the higher the coupling degree. The value range is [0, 1], and the specific disclosure is as follows:

$$C_n = \left[\frac{\prod_{j=1}^{n} u_j}{\left(\frac{1}{n}\sum_{j=1}^{n} u_j\right)^n}\right]^{\frac{1}{n}}$$

$$C_3 = \sqrt[3]{\frac{u_1 \times u_2 \times u_3}{\left(\frac{u_1 + u_2 + u_3}{3}\right)^3}} = \frac{3\sqrt[3]{u_1 \times u_2 \times u_3}}{u_1 + u_2 + u_3} \ ; \ C_2 = \sqrt{\frac{u_1 \times u_2}{\left(\frac{u_1 + u_2}{2}\right)^2}} = \frac{2\sqrt{u_1 \times u_2}}{u_1 + u_2}$$

(2) In some cases, the degree of coupling is difficult to reflect the overall "effectiveness" and "synergy" effects of the system. In order to better reflect the coupling law between subsystems, a coupling coordination index model is introduced, with the following formula. D is the coupling coordination index between each subsystem, T is the contribution of the subsystem to the overall system orderliness (comprehensive evaluation value), w_1, w_2…… w_n are the weight coefficients of u_1, u_2……u_n, and D has a value range of [0,1].

$$D = \sqrt{C_n \times T}, T = \sum_{j=1}^{n} w_j u_j, \sum_{j=1}^{n} w_j = 1$$

(3) The coupling coordination index level standard adopts a relatively mature uniform distribution method based on the analysis of different cases by scholars, and comprehensively divides the coupling coordination index level. Scholars have divided the C-value into four intervals: (0, 0.3] for low-level coupling, (0.3, 0.5] for antagonistic stage, (0.5, 0.8] for break in

stage, and (0.8, 1] for high-level coupling. The D-value is divided into three intervals: (0, 0.3] for imbalanced decline, (0.3, 0.7] for transitional development, (0.7, 1] for coordinated development, and more specifically into 10 levels.

Table 2. Classification Criteria for Coupling Coordination Index Levels

Num.	coordination Index interval	coordination Index level	Num.	coordination Index interval	coordination Index level
1	[0,0.1]	Extreme imbalance	6	(0.5,0.6]	Barely coordination
2	(0.1,0.2]	Serious imbalance	7	(0.6,0.7]	Primary Coordination
3	(0.2,0.3]	Moderate imbalance	8	(0.7,0.8]	Intermediate coordination
4	(0.3,0.4]	Mild imbalance	9	(0.8,0.9]	Good coordination
5	(0.4,0.5]	On the brink of imbalance	10	(0.9,1.0]	High quality coordination

3.1.3 Grey correlation model

In multi factor poor information systems, grey correlation facilitates the analysis of the frequency and contribution measurement of each factor's impact on the main behavior. Geometric properties refer to the geometric comparison of factor characteristics, and the coupling category involves determining the degree of coordination based on the synchronicity of factors (Li et al., 2022).

(1) Determine the dependent variable sequence (reference sequence) to characterize the main behavior of the system, and use several independent variable sequences that affect the main behavior of the system as the evaluation sequences, denoted as: $X_0=\{X_0(t),t=1,2,3,\ldots n\}$, $X_i=\{X_i(t),t=1,2,3,\ldots n\}$, $i=1,2,3,\ldots m$, Where t is time and i is each evaluation sequence. Adopting the method of range standardization to dimensionless process X_0 and X_i, eliminating the influence of order of magnitude and enhancing sequence comparability.

(2) Calculate the correlation coefficient between the reference and evaluation sequences, where $\xi_{0i}(t)$ is the correlation coefficient between X_0 and X_i at time t, and ρ is the resolution coefficient to improve the significance of the difference in correlation coefficients. The general value is 0.5. $|X_0(t)-X_i(t)|$ is the absolute difference between X_0 and X_i at time t.

$$\xi_{0i}(t)=\frac{\min_i \min_t |X_0(t)-X_i(t)|+\rho\max_i\max_t |X_0(t)-X_i(t)|}{|X_0(t)-X_i(t)|+\rho\max_i\max_t |X_0(t)-X_i(t)|}$$

(3) Calculate the grey correlation degree, average the correlation coefficients at each time point, and obtain the correlation degree between the reference sequence and the evaluation sequence, $R_{0i}=\frac{1}{n}\sum_{t=1}^{n}\xi_{0i}(t)$, $i=1,2,3,\ldots m$, $t=1,2,3,\ldots n$. R_{0i} is the grey correlation degree between the reference sequence X_0 and the evaluation sequence X_i at time t, and n is the length of the reference sequence and the evaluation sequence. Grey correlation degree emphasizes sorting, and the numerical value of correlation degree cannot fully represent the importance of analysis.

3.2 Case selection and data sources

The study chose SK Hynix as a typical case. SK Hynix was founded in February 1983 and is a semiconductor manufacturing enterprise under the South Korean SK Group. Seizing the opportunity of global semiconductor industry transfer, SK Hynix quickly rose to prominence with the strong support of the South Korean government for the semiconductor industry and the strong financial strength of SK Group. The company occupies an important position in the global semiconductor market, with products covering various types of memory and system semiconductor products such as DRAM and NAND Flash. It has now become a leading global semiconductor solution supplier. SK Hynix has a huge enterprise scale and strong capabilities. As of 2024, the total number of global employees exceeds 35000, and sales continue to grow, reaching approximately KRW 45 trillion by 2024. Its sales network covers multiple regions such as Asia, America, and Europe. SK Hynix has established multiple production bases and research and development centers worldwide to achieve optimized resource allocation and rapid market response. In South Korea, Licheon and Cheongju are its important production and research and development bases. In China, there are two large production bases, Wuxi (established in 2006) and Chongqing (established in 2012), focusing on the production and manufacturing of semiconductors. Hynix and South Korean semiconductor companies such as Samsung Electronics have jointly formed South Korea's strong competitiveness in the global semiconductor industry, driving it to become an important production and research and development base for semiconductors worldwide.

SK Hynix has high research value in ESG management. Firstly, as a globally renowned semiconductor company, its ESG management practices have a demonstrative effect on peers in the industry, providing reference and inspiration for the sustainable development of the industry. Secondly, ESG initiatives began to emerge globally in 2004, and SK Hynix began releasing sustainability reports in 2007, making it one of the earlier listed companies to respond to global ESG releases. The release time has been continuous, and it has been 17 years since the publication of this study, which has strong research value in terms of time evolution. Thirdly, the development history and global layout of SK Hynix reflect the internationalization trend and changes in the competitive landscape of the semiconductor industry, which has important reference significance for studying the policy adaptability, cultural integration, and global operational strategies of enterprises in different countries and regions. Therefore, the data for this study is sourced from the SK Hynix Sustainable Development Report of 2017, and enterprise statistical data is selected based on evaluation indicators. For missing data in individual years that have not been statistically analyzed, but the indicators are important and cannot be deleted, linear interpolation is used to supplement the values at the missing data points. The specific formula is $y = y_0 + (y_1 - y_0)(x - x_0)/(x_1 - x_0)$, where$(x_0, y_0)$and x are known values, $x_0 < x$.

4 Empirical analysis

4.1 Comprehensive evaluation values and weights of each subsystem

After standardizing the basic data of the four subsystems of economy, environment, society, and governance, the comprehensive evaluation values of the four subsystems were calculated based on the weights of the entropy method. From Table 3 and Figure 1, it can be seen that since 2007, although there have been fluctuations in some years, the overall trend of the four evaluation values has remained upward. Comparing their development speed, it was found that the evaluation value of the economic subsystem had been lagging behind the other three ESG subsystems before 2013, but after 2013, the development speed gradually took the lead, and after 2020, it was much higher than other development levels.

Overall, there have been three significant periods of decline since 2009, 2016, and 2019. The global financial crisis that began in 2008, the slowdown in global semiconductor market growth in 2016, and the increased global market volatility caused by trade frictions and economic uncertainty in 2019 have affected semiconductor demand. It also showed an exceptionally high-speed stage in the economic subsystem in 2017 and 2018, thanks to the development of 16Gb LPDDR4 memory in 2017 and the world's first 16K SRAM in 2018, greatly enhancing market competitiveness. At the same time, strong global semiconductor demand in these two years, especially for storage chips such as DRAM and NAND Flash, has driven SK Hynix's sales and profit growth. The environmental subsystem experienced two abnormally high periods in 2010 and 2014, while the social subsystem experienced significant declines in 2010, 2013, and 2020. In 2010, due to the aftermath of the financial crisis and an increase in employee turnover the previous year, the company reduced non core expenditures such as employee development and community investment. In 2013, due to the newly established Chongqing production base, the increase in short-term costs reduced investment in social responsibility projects. In 2020, due to the impact of the COVID-19 pandemic, companies were forced to prioritize core business and reduce investment in social responsibility projects. The governance subsystem experienced several growth peaks in 2014, 2018, and 2022, especially in 2018. Overall, in terms of external environment, the global economic crisis and COVID-19 pandemic, industry cyclical fluctuations, global semiconductor market demand, and trade environment are the main factors affecting SK Hynix's performance and ESG changes. Technology research and development, capacity expansion, and prioritizing core business or adjusting ESG strategic investments in certain years are key internal factors that affect their economic performance and ESG changes.

By using the entropy method and recalculating the evaluation values of the subsystems, the weights of the four subsystems during different coupling periods were calculated, as shown in Table 4. When calculating the coupling coordination relationship between ESG, the weights of the three were 0.553, 0.165, and 0.282, respectively. Through the difference in information entropy of objective data, the importance ranking of the weights of the three was W (E)>W (G)>W (S). It can be seen that in the annual sustainable development investment of enterprises, the degree of environmental change is much greater than that of society and governance, which also conforms to the fact that the environment ranks first in ESG disclosure and investment. When calculating the equilibrium relationship between the four systems of economy and ESG, the weight of economy is much greater than that of the three subsystems of ESG, reflecting that in the annual decision-making of enterprises, economic benefits are always the top priority, and the other three can only be supplementary to economic benefits.

Table 3. Comprehensive Evaluation Values of Each Subsystem

year	T(Ec)	T(E)	T(S)	T(G)	year	T(Ec)	T(E)	T(S)	T(G)
2023	0.130	0.100	0.067	0.076	2014	0.038	0.067	0.034	0.058
2022	0.142	0.104	0.071	0.087	2013	0.026	0.045	0.031	0.041
2021	0.139	0.109	0.076	0.074	2012	0.015	0.029	0.044	0.039
2020	0.097	0.106	0.070	0.095	2011	0.013	0.017	0.054	0.041
2019	0.083	0.090	0.085	0.076	2010	0.019	0.053	0.034	0.037
2018	0.117	0.073	0.071	0.106	2009	0.009	0.019	0.043	0.028
2017	0.073	0.047	0.074	0.068	2008	0.004	0.029	0.056	0.033
2016	0.037	0.036	0.064	0.049	2007	0.015	0.030	0.047	0.040
2015	0.044	0.048	0.081	0.051	--	--	--	--	--

Table 4. Weights of Each Subsystem Calculated by Entropy Method and Mean Method

Weights Calculated by Entropy Method					Weights Calculated by Mean Method				
weight	Ec	E	S	G	weight	Ec	E	S	G
W(ESG)		0.553	0.165	0.282	W(ESG)		0.333	0.333	0.333
W (EcE)	0.706	0.294			W (EcE)	0.5	0.5		
W (EcS)	0.889		0.111		W (EcS)	0.5		0.5	
W (EcG)	0.825			0.175	W (EcG)	0.5			0.5
W (EcESG)	0.570	0.238	0.071	0.121	W (EcESG)	0.25	0.25	0.25	0.25

4.2 Coupling degree and coupling coordination index of each subsystem

4.2.1 Analysis of Coupling Degree Results

By calculating the structural equilibrium of ESG through coupling degree, as well as the comprehensive synergy problem with the economic subsystem, the specific performance data is shown in Table 5 and Figures 2 to 6. According to the classification criteria of coupling degree C and coupling coordination index D, coupling degree reflects the mutual influence and dependence between subsystems. The larger the C value, the smaller the dispersion between subsystems, and the higher the coupling degree. By observing the C (ESG) values between the environment, society, and governance, as well as the C (EcESG) values of the four subsystems, the C (EcE) C (EcS) C (EcG) values of the ESG subsystems and the economy, and comparing the data of each coupling degree together to compare the development and evolution process of SK Hynix over the years, as shown in Figure 7, it can be found that the coupling degree of the four subsystems is basically in a synchronous advancing and retreating state, and the coupling degree of the vast majority of the time period is basically in the high-level coupling stage of (0.8,1), indicating that the four subsystems are in a highly interdependent and interdependent development state, and the development of each subsystem is deeply tied to the development of other subsystems.

However, observing their trends, a common time point was found, which is 2008. When detecting the coupling relationship between different subsystems of ESG and economic subsystems, 2008 was at a common low point. The values of C (EcE), C (EcG), and C (EcESG) were all in the adjustment stage of (0.5, 0.8), and even the 0.478 value of C (EcS) was in the antagonistic stage of (0.3, 0.5), indicating the impact of the global subprime crisis in 2008. Combined with SK Hynix's comprehensive evaluation of economic returns in 2008, the development of various subsystems of ESG was not closely related to the coupling relationship between the economy in that year. That is to say, even if the economic performance had a significant impact, the development of each subsystem of ESG was not very correlated with the economy. The decline in ESG performance has not been synchronized with the decline in ESG performance, and even shows growth like the social subsystem. However, the coupling relationship between ESG occurred in 2011. Based on the comprehensive evaluation values of various subsystems, it can be seen that the environmental subsystem experienced a significant decrease in 2011, resulting in a certain degree of correlation and impact decline between ESG in that year. However, they are still in the high-level coupling stage of (0.8,1). By observing the coupling degree of each subsystem, and due to the decrease in the evaluation value of the environmental subsystem, the coupling degree between the environmental subsystem and other subsystems significantly decreased that year.

4.2.2 Analysis of Coupling Coordination Index Results

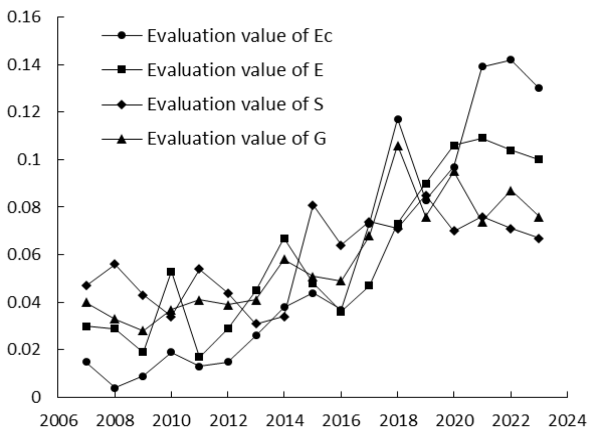
Although coupling degree reflects the degree of mutual influence between systems, it is difficult to reflect the overall "efficiency" effect of the system. In some periods, coupling degree is high, but due to the low development level of each subsystem, low-level high coupling effects will occur. In order to better reflect the coupling law between subsystems and refer to the contribution of subsystems to the overall system orderliness, analyzing the coupling coordination index D can better reflect the nonlinear process from disorder to order in the structure. Observing Figures 2 to 6, since 2007, the D (ESG) values between the environment, society, and governance, as well as the D (EcESG) values of the four subsystems, the D (EcE) D (EcS) D (EcG) values of the ESG subsystems and the economy, have all been in a gradual upward trend. Although there were significant declines in 2008 and 2016, there were two small peaks in the coupling coordination index related to the economic subsystems in 2010 and 2018. Observing Figure 8 and comparing the trends of different coupling coordination indices since 2007, it is found that the evolution process of coupling coordination indices calculated with the economic system is surprisingly consistent. However, the coupling coordination index D (ESG) value between the environment, society, and governance has a different evolution speed. Before 2016, the D (ESG) value was higher than the other coupling coordination index D values, but after 2016, the growth rate significantly decreased and gradually decreased compared to the other coupling coordination index D values. It can be seen that after considering the comprehensive evaluation value of each subsystem (contribution value or development level to the overall system), the mutual influence relationship between subsystems is more valuable than simply coupling degree, especially D (ESG). The speed of change in the level of development between environment, society, and governance is significantly lower than that of the economic subsystem.

After analyzing the evolution trend of the coupling coordination index, their development levels were analyzed through data analysis. Referring to the contribution of subsystems to the overall system orderliness, the overall coupling coordination index level showed a significant decrease compared to the coupling degree level, from a high coupling degree of 0.8 or above to a low-level coordination state of 0.5 or below, indirectly indicating that the development level of each subsystem is not very high and the overall system is at a low level. The coupling coordination index D (ESG) values of the three subsystems of environment, society, and politics are already at the highest level, but they are also in a development state from (0.3, 0.4] mild imbalance to (0.4, 0.5] near imbalance. The other coupling coordination index D (ESG) values are related to the level of economic development and are in a development state from (0.1, 0.2] severe imbalance to (0.3, 0.4] mild imbalance. From the perspective of the coordination level of the three-point method, except for the coupling coordination index D (ESG) values of the ESG three subsystems, which are in the transitional development category of (0.3, 0.7], the others are even in the transition from the imbalanced decline category of (0, 0.3] to the transitional development category of (0.3, 0.7].

Table 5. Coupling Degree and Coupling Coordination Index of Each Subsystem (Weight Calculated by Entropy Method)

year	C(ESG)	D(ESG)	C(EcE)	D(EcE)	C(EcS)	D(EcS)	C(EcG)	D(EcG)	C(EcESG)	D(EcESG)
2023	0.986	0.430	0.991	0.346	0.947	0.341	0.966	0.341	0.968	0.329
2022	0.988	0.442	0.988	0.360	0.943	0.356	0.970	0.359	0.968	0.343
2021	0.984	0.439	0.993	0.359	0.956	0.355	0.952	0.348	0.965	0.339
2020	0.985	0.446	0.999	0.316	0.986	0.305	1.000	0.312	0.988	0.310
2019	0.998	0.437	0.999	0.291	1.000	0.288	0.999	0.285	0.998	0.289
2018	0.983	0.434	0.973	0.318	0.969	0.330	0.999	0.339	0.976	0.316
2017	0.982	0.396	0.977	0.252	1.000	0.270	1.000	0.268	0.985	0.255
2016	0.972	0.364	1.000	0.190	0.962	0.195	0.989	0.196	0.971	0.196
2015	0.973	0.388	0.999	0.213	0.957	0.215	0.997	0.213	0.972	0.217
2014	0.962	0.371	0.961	0.211	0.999	0.194	0.978	0.201	0.962	0.213
2013	0.988	0.338	0.965	0.175	0.996	0.163	0.975	0.168	0.977	0.179

2012	0.984	0.332	0.949	0.134	0.870	0.126	0.893	0.131	0.924	0.146
2011	0.894	0.322	0.994	0.119	0.797	0.119	0.858	0.125	0.846	0.131
2010	0.981	0.343	0.879	0.159	0.956	0.140	0.946	0.144	0.937	0.168
2009	0.947	0.305	0.933	0.105	0.756	0.098	0.853	0.102	0.860	0.117
2008	0.960	0.336	0.628	0.084	0.478	0.067	0.594	0.072	0.691	0.108
2007	0.984	0.337	0.939	0.134	0.852	0.125	0.888	0.130	0.917	0.147



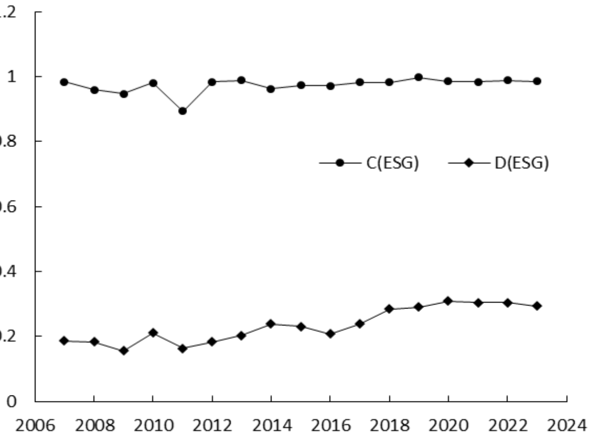
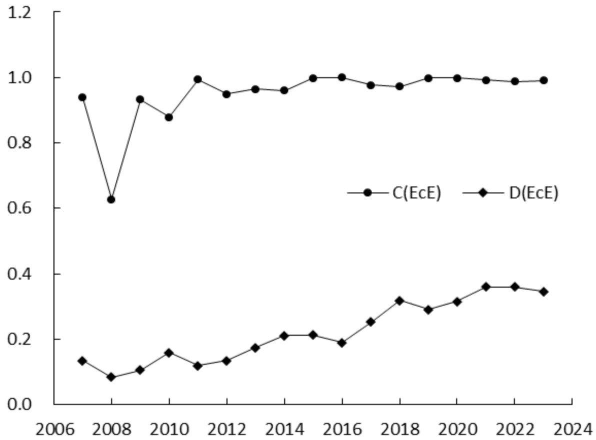


Figure 1. Comprehensive evaluation values of each subsystem (Left)

Figure 2. Coupling Degree and Coupling Coordination Index of ESG (Right)



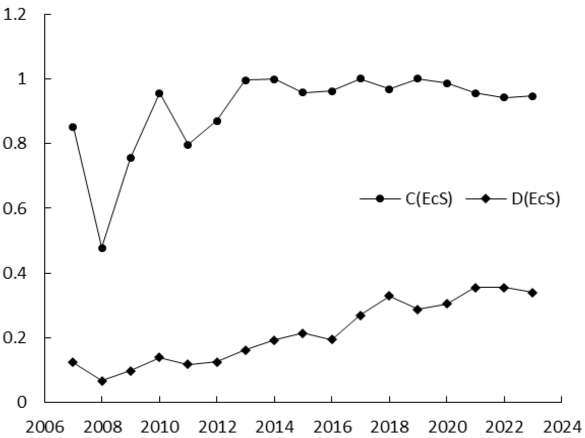
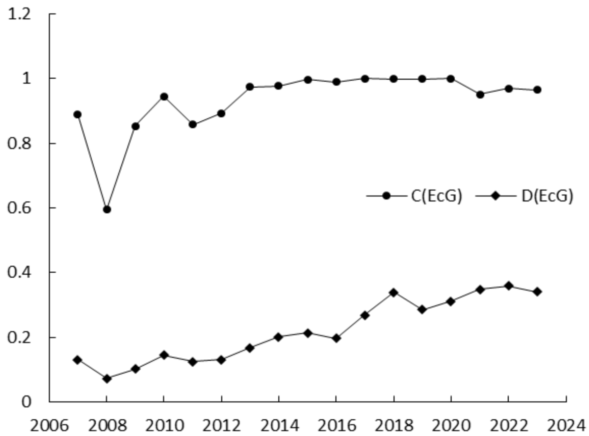


Figure 3. Coupling Degree and Coupling Coordination Index of Economy and Environment (Left)

Figure 4. Coupling Degree and Coupling Coordination Index of Economy and Society (Right)



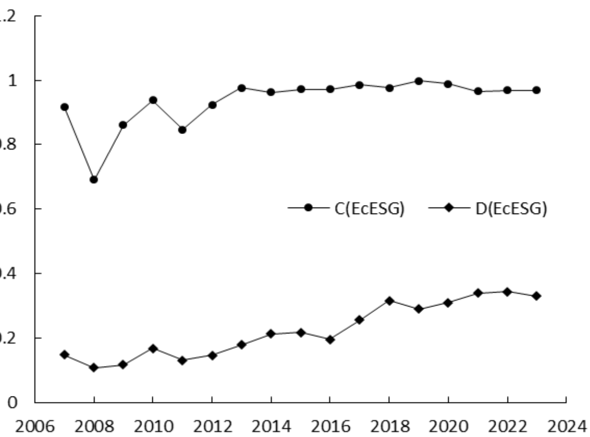


Figure 5. Coupling Degree and Coupling Coordination Index of Economy and Governance (Left)

Figure 6. Coupling Degree and Coupling Coordination Index of Economy and ESG (Right)

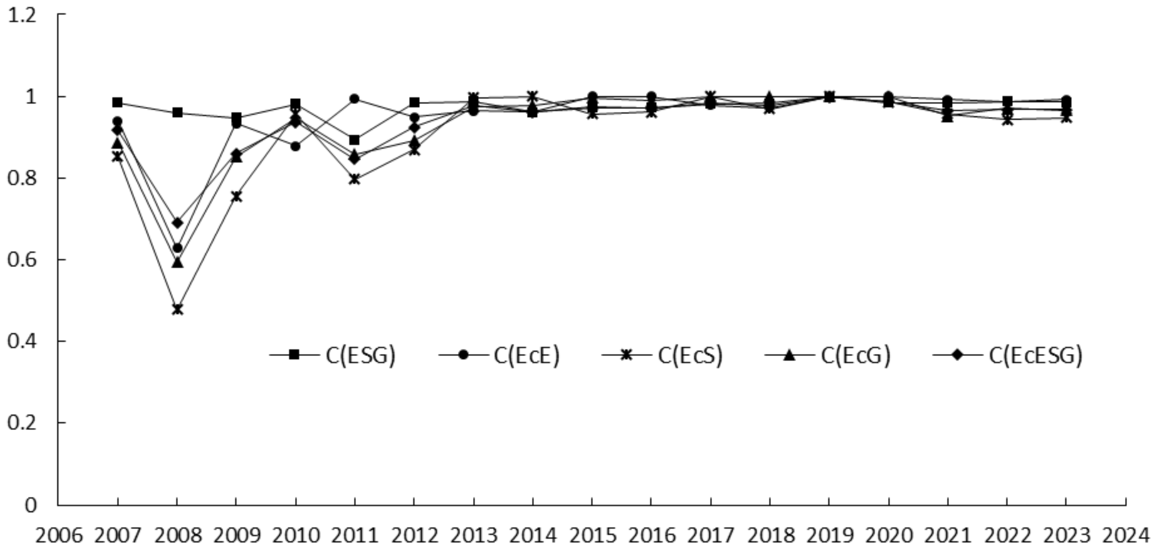


Figure 7. Comparison of coupling degrees of different subsystems

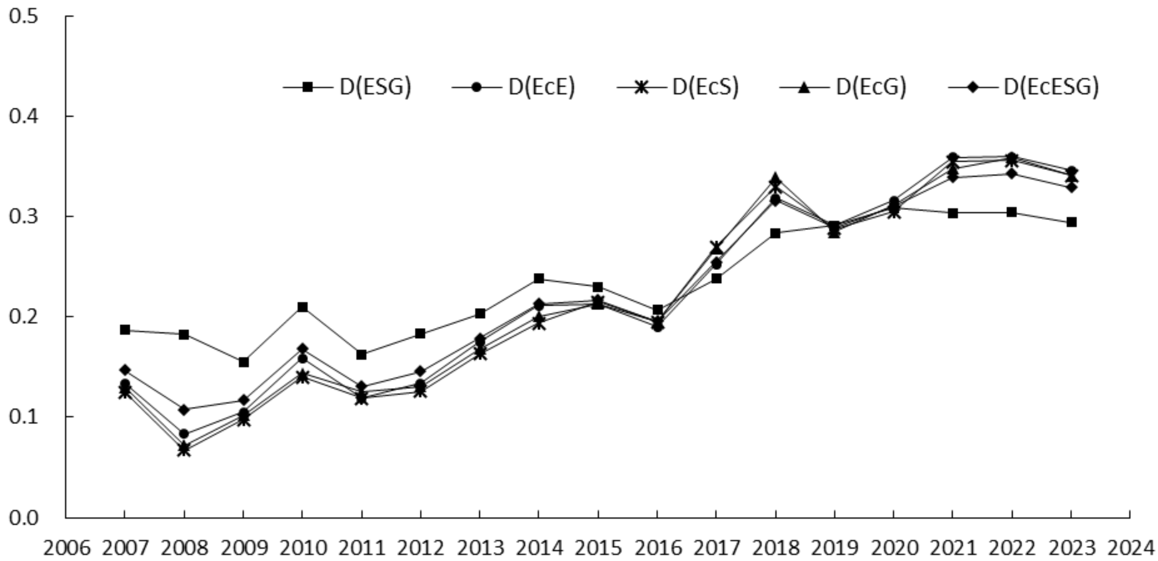


Figure 8. Comparison of Coupling Coordination Index of Different Subsystems (Weight Calculated by Entropy Method)

Due to the use of entropy method to calculate the weights of each subsystem in the calculation of the coupling coordination index mentioned above, the weights of the ESG three subsystems are the highest in the environmental system. When calculating the coupling coordination index between ESG and the economic subsystem, the entropy method calculates the weights of the economic factors, which are the highest. In order to better analyze their level of coordinated development and avoid errors with reality, some calculation models calculate their weights equally, as shown in Table 4. By calculating the coupling coordination indices using the mean method, as shown in Figure 9, it was found that the D (ESG) values between the environment, society, and governance, as well as the D (EcESG) values of the four subsystems and the D (EcE), D (EcS), and D (EcG) values of the ESG subsystems and the economy, are still in an upward trend in evolution, and the overall coordination level is still relatively low, basically at the coordination level of (0.4, 0.5) close to imbalance or below. These two results are consistent with the weight calculation results of the entropy method. However, when comparing the evolutionary differences in the coupling coordination index of different systems, it was found that the D (ESG) value between environment, society, and governance has always been higher than the D values of other coupling coordination indices, while the D (EcS) value between economy and society has always been lower than the D values of other coupling coordination indices. That is to say, in the ESG performance of enterprises, combined with the previous comprehensive evaluation value T (S), the synchronization effect between the economy and society is lower, and the social responsibility performance greatly drags down the overall level of collaborative development balance.

Table 6. Coupling Coordination Index of Each Subsystem (Weight Calculated by Mean Method)

year	D(ESG)	D(EcE)	D(EcS)	D(EcG)	D(EcESG)	year	D(ESG)	D(EcE)	D(EcS)	D(EcG)	D(EcESG)
2023	0.430	0.337	0.183	0.316	0.300	2014	0.371	0.225	0.084	0.216	0.218
2022	0.442	0.349	0.195	0.334	0.313	2013	0.338	0.186	0.069	0.182	0.187
2021	0.439	0.351	0.195	0.318	0.310	2012	0.332	0.144	0.061	0.156	0.171
2020	0.446	0.319	0.160	0.311	0.302	2011	0.322	0.122	0.063	0.153	0.163
2019	0.437	0.293	0.155	0.282	0.288	2010	0.343	0.177	0.061	0.162	0.182
2018	0.434	0.304	0.176	0.334	0.299	2009	0.305	0.114	0.050	0.126	0.146
2017	0.396	0.242	0.140	0.266	0.254	2008	0.336	0.101	0.045	0.105	0.145
2016	0.364	0.190	0.099	0.206	0.212	2007	0.337	0.145	0.062	0.155	0.173
2015	0.388	0.215	0.116	0.218	0.233	--	--	--	--	--	--

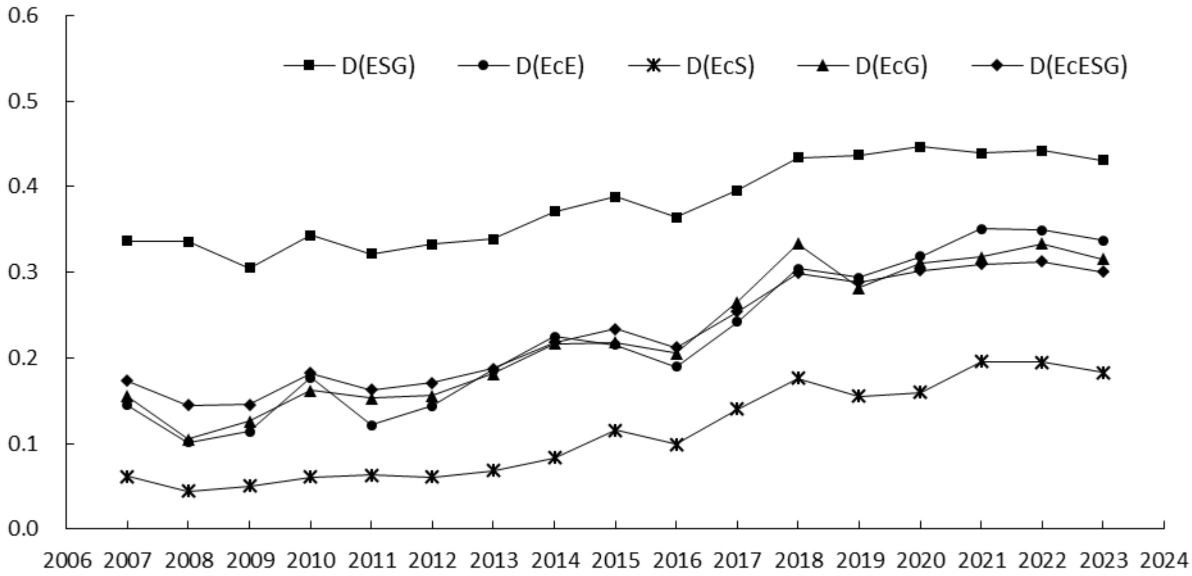


Figure 9. Comparison of Coupling Coordination Index of Different Subsystems (Weight Calculated by Mean Method)

4.3 Grey correlation between ESG subsystem and economy

Through the results of the coupling degree and coupling coordination index mentioned above, the mutual influence and collaborative evolution between the environment, society, and governance, as well as between ESG subsystems and economic performance, have been basically understood. Although it can be seen to some extent that the structural balance between ESG alone leads to better performance of enterprises, once the element of economic performance is added, the evaluation value of the overall structural balance relationship will be greatly reduced, which means that their structural relationship is influenced by economic performance. To further explore the relationship between ESG corporate performance and the economy, a grey correlation model was used to analyze whether they were constrained by the economy. The calculation results are shown in Table 7 and Figure 10. By observing the data performance, there is no clear pattern in the evolution of the grey correlation coefficients between ESG subsystems and economic performance over the years. By fitting their linear trend lines to explore the evolution trend, it can be seen that the grey correlation coefficients between ESG and the economy are generally in a downward trend. Combined with the comprehensive evaluation results that they are all in an upward stage, it can be concluded that although they are all on the rise, the magnitude of the increase is obviously different. The overall decrease in grey correlation coefficients indicates that the growth rate of ESG subsystems is smaller than that of the economic system, and the growth rate between them is gradually forming a scissor effect. Therefore, the coupling coordination index between ESG and the economy has always been at a low level, which can be explained to some extent. Again, based on the final calculated grey correlation R value between ESG and the economy, R(EcG)> R(EcE)> R(EcS), That is to say, the governance subsystem has the greatest correlation with the economy, followed by the environmental subsystem, and finally the social subsystem, reflecting that in the ESG decision-making of enterprises, the most important factor is actually governance, and social value performance is considered last. From the perspective of enterprise management, governance factors are actually most related to the economic performance of the enterprise, and they are also the internal performance of the enterprise. Relatively speaking, the importance of the environment and society in operation is far less than that of governance. Even the social performance of the enterprise may be the most external reference for operation, which to some extent verifies the profit oriented nature of the enterprise. Even when doing social responsibility (CSR), it is fundamentally for the profit-making nature of the enterprise.

Table 7. Grey Correlation Between the Three Subsystems (Environment, Society, and Governance) and the Economy

year	ξ(EcE)	ξ(EcS)	ξ(EcG)	year	ξ(EcE)	ξ(EcS)	ξ(EcG)
2023	0.443	0.371	0.405	2014	0.450	0.932	0.661
2022	0.379	0.342	0.393	2013	0.562	0.902	0.729
2021	0.444	0.371	0.355	2012	0.643	0.565	0.608
2020	0.758	0.577	1.000	2011	0.905	0.480	0.573
2019	0.794	0.976	0.883	2010	0.410	0.715	0.687
2018	0.347	0.445	0.783	2009	0.716	0.527	0.667
2017	0.485	1.000	0.943	2008	0.484	0.416	0.556
2016	1.000	0.579	0.770	2007	0.615	0.538	0.604
2015	0.878	0.507	0.879	R	0.607	0.602	0.676

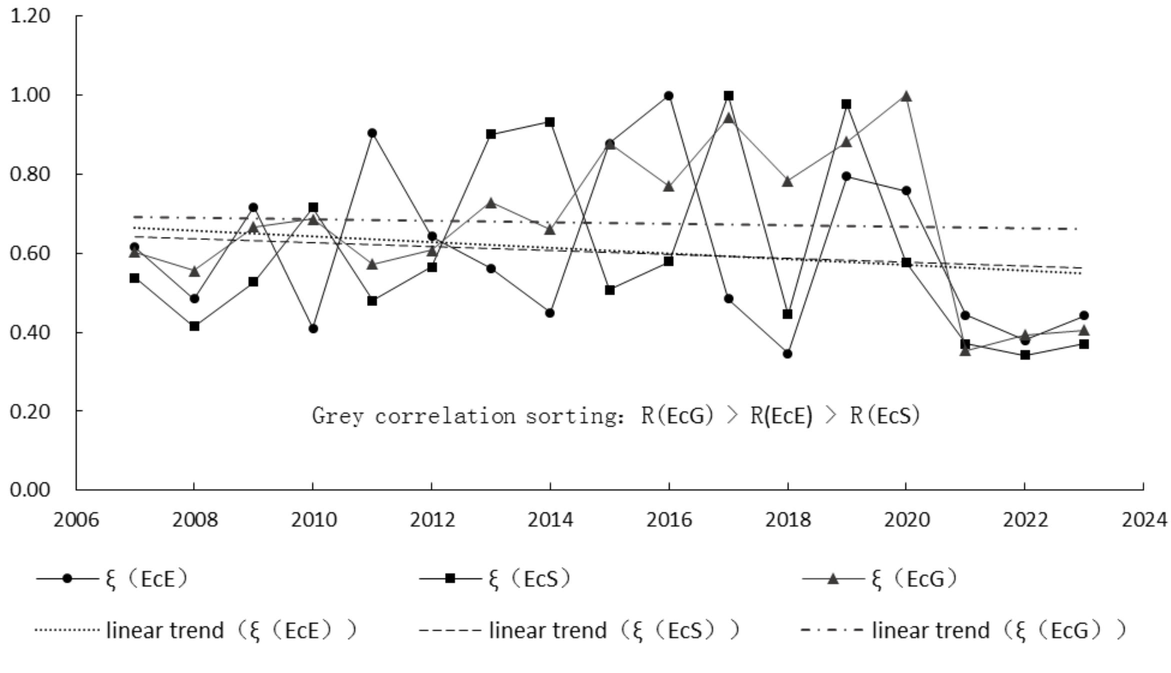


Figure 10. Grey Correlation Degree and Linear Trend of ESG Three Subsystems with the Economy Respectively

5 Research Conclusions

5.1 Conclusion and Discussion

This study analyzes the structural balance and coordinated development of investment and implementation at various levels of environmental, social, and governance in the ESG management process of enterprises from a structuralist perspective. At the same time, it analyzes the correlation and impact relationship between ESG and the economic system. The study selected

SK Hynix, a well-known electronic technology company in the world, as the case study object. Through mathematical statistical models such as entropy method, coupling coordination index, and grey correlation degree, the study analyzed the correlation and coordination evolution process and trend between the enterprise economy and ESG subsystems over the past 17 years. In structuralist logic, it breaks through the analysis of a single dimension and reveals the deep contradictions and dynamic equilibrium mechanisms between subsystems. The specific conclusion is as follows.

Firstly, an evaluation system for the enterprise's economic and ESG subsystems has been constructed, with the economic subsystem comprehensively evaluating assets, returns, costs, and other aspects; The environmental subsystem is divided into three series of indicators: environmental investment, energy and raw material utilization, and environmental impact; The social subsystem includes four levels: employees, communities, consumers, and collaborative companies; The governance subsystem is divided into several levels: governance structure, shareholder rights, labor relations, ethical risks, and compliance/transparency. Through the information entropy difference of SK Hynix's objective data, th e weight ranking of ESG is W (E)>W (G)>W (S). It can be seen that when companies invest in sustainable development every year, the degree of environmental change is much greater than that of society and governance, which also conforms to the fact that the environment ranks first in ESG disclosure and investment. When calculating the equilibrium relationship between the four systems of economy and ESG, the weight of economy is much greater than that of the three subsystems of ESG, reflecting that in the annual decision-making of enterprises, economic benefits are always the top priority, and the other three items can only be supplementary to economic benefits. According to the weight calculation of the entropy method, the comprehensive evaluation values of the four subsystems have generally maintained an upward trend. The evaluation value of the economic subsystem lagged behind the other three ESG subsystems before 2013, but its development speed gradually led after 2013 and far exceeded other development levels after 2020. The investment in environment, society, and governance does not increase synchronously, but presents a phased focus (such as prioritizing environmental governance during crisis periods and strengthening social investment during expansion periods). This conclusion can help companies optimize ESG resource allocation, avoid a one size fits all strategy, and achieve dynamic balance.

Secondly, by calculating the structural equilibrium status of SK Hynix ESG through coupling degree, as well as the comprehensive collaborative evolution and development trend with the economic subsystem, the coupling degree of the four subsystems is basically in a synchronous state of advance and retreat, and the coupling degree during most of the time is basically in a high-level coupling stage, indicating that the four subsystems are in a highly interdependent and interdependent development state, and the development of each subsystem is deeply tied to the development of other subsystems. When faced with a crisis in corporate development, ESG and economic returns exhibit an antagonistic development state, and companies even enhance their brand value and social responsibility by reverse engineering ESG investments. There may be "crowding out effects" and "leverage effects", such as a downturn in corporate economic returns or excessive investment in environmental technology, which can compress social projects and lead to imbalances between subsystems. The strength of corporate governance directly affects the efficiency of achieving environmental and social goals.

Again, in order to balance the low-level high coupling effects and better reflect the coupling laws between subsystems, the overall coupling and coordination evolution process between ESG subsystems and the economy is gradually increasing. However, the level of collaborative development has significantly decreased compared to the level of coupling, and the overall development is in a state of mild to near imbalance, with the evolution process upgrading from imbalance decline to transitio nal development. After considering the contribution value to the overall system, the mutual influence relationship between each subsystem is more valuable than simply coupling degree. The development level of ESG subsystems is not yet very high, and the overall level is relatively low. The evolution process of the coupling coordination index calculated with the economic system is surprisingly consistent, but the coordinated development speed between the environment, society, and governance has gone through a process of high to low, and finally significantly lower than the development process of the economic subsystem. At the same time, the synchronization effect between the economy and society is lower, and the performance of social responsibility greatly drags down the overall balance of collaborative development.

Finally, to further explore the constraining relationship between ESG subsystems and economic factors, as well as their dynamic adjustment of structural adaptability over time. The overall grey correlation coefficient between ESG subsystems and the economy is in a downward trend, indicating that the growth rate of ESG subsystems is smaller than that of the economic system, and a scissors gap is gradually forming, explaining the reason why the coupling coordination index between ESG and the economy has always been at a low level. In terms of the overall grey correlation between ESG and the economy, R(EcG)> R(EcE)> R(EcS), The governance subsystem has the greatest correlation with the economy, followed by the environmental subsystem, and finally the social subsystem, reflecting that in the ESG business decision-making of enterprises, the importance of the environment and society in operation is far less than that of governance, and even the social performance of enterprises may be the most external reference for operation, which to some extent verifies the profit oriented nature of enterprises. Even when doing social responsibility (CSR), the most essential thing is still for the profit-making nature of enterprises.

5.2 Research Implications

Firstly, for the case company SK Hynix, it is necessary to confront the conflict between short-term economic pressures and long-term ESG goals. For example, in 2017, SK Hynix expanded its production capacity due to the industry boom cycle, resulting in a deterioration of environmental indicators, but an increase in economic indicators. In the long run, the transformation of corporate ESG from "compliance driven" to "strategic driven" requires the development of an "ESG economic win-win" strategy. Simultaneously emphasizing the refinement and promotion of industry benchmark practices, ESG has become politicized worldwide, with more American institutions adopting a "green silence" model to avoid discussing ESG, resulting in a deviation in global understanding of ESG. Many companies have begun to abandon their pursuit of ESG, and SK Hynix's cross-border operational characteristics have made its ESG practices influenced by policies from multiple countries. Research can provide case support for international organizations (such as ISO and UNGC) to promote the globalization of ESG standards.

Secondly, for ESG decision-makers of enterprises, the structural balance of ESG does not require the subsystems to develop synchronously and at an equal speed. It can implement a certain strategy of unbalanced development to achieve long-term coordination. Enterprises need to gradually identify the symbiotic nodes between ESG and the economic system, such as reducing energy consumption costs (economic) and carbon emissions (environmental) through green technology research and development innovation, enhancing decision-making inclusiveness (governance) through employee diversity management, and indirectly promoting long-term economic benefits. At the same time, attention should be paid to the game between institutional constraints and strategic initiative. Enterprises need to find a balance between external policies (such as carbon emission regulations) and internal resource constraints.

Finally, for policy makers, it is necessary to strengthen ESG regulation and institutional design, and study the phased relationship between ESG and the economic system revealed. For example, in special years such as economic crises and environmental investment suppression, the government needs to design differentiated ESG incentive policies (such as tax incentives and green credit). By identifying serious imbalances between ESG subsystems (such as governance lag leading to inefficient environmental investment) for risk warning, regulatory agencies can be prompted to strengthen legislation or standard setting for weak links (such as corporate anti-corruption mechanisms and supply chain transparency). Enhance the confidence of investors and the public in ESG assets, and promote the transformation of the capital market towards sustainability. The main mechanism behind this improvement is better corporate information governance, which includes increasing information transparency, enhancing information sharing, and reducing information asymmetry. These improvements, in turn, have led to improvements in environmental information disclosure, optimization of supply chain management, and reduction of agency costs (Zhou et al., 2025).

5.3 Shortcomings and Future

The study of the internal structure of ESG from a structuralist perspective is a complex issue, and there is still a lot of research space for this study to explore from the perspective of enterprises. The construction of the indicator system in this study adopts the principle of combining science and convenience. The indicators are basically the units used by the case enterprises to release sustainable reports since 2007. However, the indicators released by each enterprise are different, and different case studies may affect the consistency of the results due to the differences in the indicator system. Secondly, this study calculated the coupling and coordination relationships between various subsystems of ESG and the economic system. However, the structural equilibrium and coupling issues within each subsystem are also worth studying. Clarifying the internal structural relationships is more conducive to analyzing the causes and mechanisms of the relationships between external system frameworks. Once again, the factors influencing the structural coupling of ESG may not be limited to the economic performance of the enterprise itself. Changes in external policy systems, international rules, and international political awareness of the environment all have an impact on the decision-making performance of ESG in enterprises. At the same time, the measurement of the mutual influence between various subsystems of enterprise ESG and their relationship with economic performance, coupled coordination index, and grey correlation degree can only measure the degree of mutual influence. However, the current methods still have certain limitations in determining which one is more suitable as the independent variable.

From a research perspective, it is necessary to further improve the construction of the indicator system in the future, pay more attention to the relationship between ESG and external variables, and combine qualitative research to focus on the structural balance and imbalance relationship within subsystems. In terms of research methods, more diverse analysis methods can be adopted, such as machine learning prediction or system dynamics simulation of the long-term evolution of ESG and the economy. And adopting comparative studies of multiple cases, comparing ESG structural equilibrium models in different industries and countries' policy environments, expanding the time interval, and achieving the improvement from specific conclusions of cases to general conclusions, is conducive to the further emergence of theory.

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