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# 創刊詞

## 立足亞太，匯智全球——共創經濟管理研究新篇章

在經濟全球化與區域一體化交織並進的21世紀，亞太地區憑藉強勁的增長活力、深厚的市場潛能與多元的制度生態，日益成為世界經濟格局中舉足輕重的板塊。與此同時，數字技術的顛覆性突破、人工智能的深度嵌入、治理範式的持續重構，正深刻重塑著企業運行邏輯與宏觀經濟機制。真正有價值的經管探索，既要紮根區域實踐、回應現實之需，也要拓寬全球視野、前瞻未來之潮。正是在這樣的時代環境下，《亞太經濟管理學刊》（Asia Pacific Business and Economics）應運而生。為全球經濟管理領域的研究者、政策制定者、行業實踐者搭建開放嚴謹、多元包容、面向前沿的國際化學術交流平臺，是本刊創刊的初心，也彰顯了本刊的學術定位與價值追求。

本刊秉持“立足亞太、放眼全球、聚焦前沿、賦能實踐”的辦刊理念，堅守思想性、創新性、專業性、實踐性的學術準則，聚焦數字經濟、人工智能與經濟治理、產業集群與轉型升級、區域經貿合作與全球價值鏈、企業戰略與管理創新、公共治理與營商環境優化等核心領域，宣導跨學科交融、跨區域對話、跨領域互鑒，推動學術研究成果轉化為產業升級動力、政策優化參考、企業發展指引，助力亞太經濟高質量發展與治理效能提升。

創刊啟新程，篤行方致遠。學術之路，貴在堅守初心、重在深耕細研、成在聚力同行。期刊將始終恪守學術初心、嚴守學術規範、深耕學術研究，以開放包容的胸懷彙聚真知灼見，以求真務實的態度探索發展之道，培育兼具理論深度、實踐溫度、國際視野的一流學術沃土。期刊必將在時代浪潮中砥礪深耕、穩步成長，成為展現亞太經管研究前沿成果、推動區域學術交流互鑒、助力全球經濟治理創新的重要學術陣地。

《亞太經濟管理學刊》主編、嶺南大學商學院副院長、教授

史珊珊博士

# Research on the ESG Transformation Pathways and Strategies for Domestic High-Emission Enterprises under the Dual-carbon Goals

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**Abstract:** Transformation has evolved from passive compliance into a core strategic initiative for high-emission enterprises. This study selects nine sample firms covering three typical high-emission industries (power, steel and chemical industries), and adopts policy text analysis, multi-case comparison and grounded theory to explore how dual-carbon pressure affects corporate ESG transformation paths alongside internal adaptive capabilities. The results show that external transformation pressures mainly stem from carbon regulatory constraints, green market demand and carbon trading market volatility, while internal driving capabilities consist of carbon accounting capacity, green technology reserves, financial support and internal governance quality. At present, most high-emission enterprises suffer from mismatched external pressure and internal capacity, accompanied by prominent dilemmas including unclear carbon asset valuation, insufficient green technology application and non-standard ESG information disclosure. Moreover, significant industrial heterogeneity leads to differentiated ESG transformation strategies among high-carbon enterprises. Accordingly, this paper establishes an integrated theoretical framework of "dual carbon pressure-enterprise capability-ESG response" targeted at industrial differences. The findings complement existing theories on corporate green and ESG transformation under carbon neutrality constraints. Besides, they provide practical operational guidance for high-emission enterprises to break transformation bottlenecks and realize coordinated development of carbon reduction and corporate value growth, as well as valuable references for governments to formulate differentiated industrial green policies and optimize green financial supervision systems

**Keywords:** dual carbon target; high-emission enterprises; ESG transformation; differentiated transformation paths

**JEL Classification:** G18; Q54; Q56; Q58

## 1 Introduction

Global greenhouse gas emissions keep pushing climate risks upward, and all nations have accelerated the formulation of carbon reduction policies. In 2020, China formally put forward the strategic goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. This commitment serves as both China's international climate pledge and the core guideline for domestic industrial green upgrading. In 2026, the General Office of the State Council issued updated documents to raise standards for energy conservation and carbon reduction, clearly defining the power, steel and chemical sectors as core industrial emission reduction subjects. Statistical data confirms that the three industries, namely the electricity, steel and chemical industries, together contribute more than 70% of China's total industrial carbon emissions, making them the primary carriers for delivering dual-carbon tasks.

As an integrated evaluation system covering environmental, social and non-financial governance indicators, ESG has evolved from voluntary corporate social responsibility reporting to a mandatory strategic management

tool for high-emission firms. ESG is a comprehensive evaluation framework covering the environmental, social and governance dimensions. The environmental dimension takes carbon accounting and low-carbon technological renovation as core priorities under dual-carbon constraints, covering greenhouse gas control, resource recycling and pollution abatement. The social dimension focuses on employee rights protection, green supply chain management and community sustainable development. The governance dimension includes the setting of board ESG committees, climate risk management and standardized information disclosure mechanisms. Different from the traditional single shareholder value maximization logic, the ESG governance paradigm balances the reasonable demands of multiple stakeholders, and becomes a standardized management tool for high-emission enterprises to respond to carbon risks and rebuild long-term competitive advantages.

Nevertheless, a prominent disconnection exists between academic research and real corporate operations. Although China's "1+N" dual-carbon policy framework and multi-layer ESG disclosure rules have taken initial shape, most high-emission enterprises lack clear, industry-matched transformation roadmaps. Two critical research gaps remain unaddressed in existing literature. First, prior scholars rarely construct an integrated analytical framework to interpret the dynamic coupling between external institutional pressure and firms' heterogeneous internal resources. Second, few cross-industry multi-case comparative analyses have been carried out to classify heterogeneous transformation paths and their matching strategic systems. To fill these research gaps, this paper conducts grounded multi-case analysis based on nine representative listed firms across three high-emission sectors, and summarizes four typical ESG transformation modes with targeted implementation strategies.

Most existing ESG transformation literature adopts a single-dimensional analytical perspective, either overemphasizing the binding force of external policies or only discussing the supporting role of internal resource endowments. This paper integrates institutional theory and the resource-based view to build the "dual carbon pressure-enterprise capability-ESG response" analytical framework. The framework systematically clarifies the interactive mechanism between external carbon constraints and internal corporate capacity, supplementing theoretical interpretations of transformation driving logic.

In addition, most relevant studies rely on single-industry or single-case evidence, lacking horizontal comparative analysis of power, steel and chemical industries. Through standardized multi-case coding and cross-group comparison, this paper distinguishes four transformation paths with clear applicable boundaries. The findings remedy the defects of macro descriptive research and expand the application scope of corporate sustainable development theory under dual-carbon constraints.

Current research generally proposes one-size-fits-all transformation models for all high-emission enterprises. This paper designs differentiated strategic portfolios according to industrial attributes, profitability and R&D reserves of firms, which can resolve practical dilemmas such as ambiguous transformation directions and mismatched resource allocation, helping enterprises balance short-term transformation expenditures and long-term low-carbon value appreciation.

For government regulators, micro empirical evidence extracted from nine sample firms provides decision-making references for formulating categorized industrial green policies. Differentiated policy tools can replace unified carbon reduction standards, reduce the

transformation impact on different types of enterprises, and realize synergies between policy incentives and corporate low-carbon behaviors.

The remaining of this paper is organized as follows: Chapter 2 provides a literature review focusing on the driving factors and mechanics for ESG transformation. Chapter 3 details the research methodology for the study. Chapters 4 provides an in-depth analysis of nine sample companies from the three high-emission industries. Chapter 5 constructs an ESG strategy system based on the differentiated transformation pathways. The paper concludes with a Chapter 6.

## 2 Literature Review

### 2.1 Evolution of ESG Disclosure Systems and International Standard Comparison

China's ESG information disclosure framework has gone through four distinct development stages. The voluntary reporting phase lasted from 2003 to 2015, during which enterprises released environmental reports without mandatory regulatory requirements. The preliminary regulation stage covered 2016–2020, accompanied by the launch of China's green financial framework. The mandatory expansion stage (2021–2023) was driven by the dual-carbon goals, while the standardized construction stage began in 2024 after the release of national double-materiality disclosure guidelines. At present, CSI 180 and STAR 50 constituent stocks as well as central SOEs are required to publish ESG reports, yet data distortion, insufficient third-party verification and widespread greenwashing remain prominent practical problems [1].

Globally, two mainstream sustainable reporting systems form a complementary structure. The ISSB issued IFRS S1 and IFRS S2 based on financial materiality and the TCFD four-pillar framework, requiring full disclosure of Scope 1, 2 and 3 greenhouse gas emissions. The EU's CSRD and ESRS standards adopt the double-materiality principle, simultaneously demanding disclosure of corporate environmental externalities and climate financial risks [2]. GRI standards focus on multi-stakeholder impact evaluation, and have formed compatible reporting logic with ISSB norms to lower disclosure costs for multinational enterprises [3]. Comparative research proves that unified accounting standards can boost cross-border investor confidence, but gaps between nominal rules and actual implementation weaken policy effects. China's localized double-materiality system can provide unique experience for coordinating global disclosure standards [5].

### 2.2 Driving Factors and Mechanisms of Corporate ESG Transformation

The formation of corporate ESG transformation willingness and capacity is jointly determined by external institutional forces and internal resource conditions. Externally, three layers of pressure work together: rigid constraints from carbon trading and environmental inspections, normative pressure from green investor preferences, and imitation pressure within industrial competition [6,8]. Internally, senior management's environmental cognition, low-carbon technology stock and corporate financing scale determine the feasibility of green investment [7].

The ESG three-dimensional framework affects corporate operations through differentiated channels. The environmental dimension relies on energy-saving technological renovation to cut emission costs; the social dimension optimizes stakeholder relations to enhance operational resilience; the governance dimension improves long-term climate risk decision-making mechanisms. Coordination between internal and external drivers can simultaneously lift environmental and financial performance, a conclusion supported by multiple empirical studies [11].

### 2.3 Industry-Specific Research on High-Emission Sectors' Transformation Paths

Existing literature has formed segmented conclusions for power, steel and chemical industries. The low-carbon transition of the power industry centers on building a new energy system supported by wind, solar and CCUS equipment, while traditional thermal power firms face prominent stranded asset risks and short-term profit pressure [18]. The steel industry is restricted by severe blast furnace long-process carbon lock-in, and its transformation follows a three-stage logic: energy efficiency optimization in the short run, electric furnace popularization in the medium run, and hydrogen metallurgy breakthroughs in the long run. The sector's transformation is closely linked to downstream green steel procurement demand [13]. The chemical industry features diversified product structures and heterogeneous technical routes, relying on park circular symbiosis, green hydrogen substitution and high-value material expansion to complete systematic decarbonization [10].

Nevertheless, most existing studies only analyze a single industry and fail to conduct horizontal comparisons of transformation modes based on enterprises' resource endowments, lacking categorized strategic guidance for different types of firms.

### 2.4 Transformation Challenges and ESG Value Creation Logic

High-emission enterprises share universal transformation obstacles, including high commercialization costs of disruptive low-carbon technologies, insufficient cross-industry coordination mechanisms and incomplete internal ESG governance systems [20]. A series of empirical studies confirm the positive correlation between ESG performance and corporate value. Carbon emission trading pilot policies can significantly raise manufacturing firms' green total factor productivity; energy-intensive enterprises with high ESG ratings exhibit lower stock market volatility [21]. Optimized board structure and ESG-linked executive compensation can restrain corporate short-sighted behaviors and lift long-term environmental output [25]. McKinsey's five-channel value creation theory summarizes that standardized ESG management improves corporate competitiveness via revenue expansion, cost reduction, risk control, human resource optimization and high-quality investment allocation [23]. The above research lays a theoretical foundation for the case analysis and strategic design of this paper.

## 3 Research Aims and Methodology

### 3.1 Research Aims

China's dual-carbon strategic target contains two sequential core objectives: carbon peaking by 2030 and carbon neutrality by 2060. Carbon peaking means industrial carbon emissions reach a historical maximum value and then maintain a sustained downward trend, realizing decoupling between economic expansion and fossil energy consumption. Carbon neutrality requires enterprises to offset net carbon emissions within a fixed cycle via energy conservation, carbon sink afforestation and CCUS carbon capture technologies.

This paper sets three core research objectives. First, it deconstructs the dual driving system of ESG transformation, sorts three categories of external institutional pressure and four types of internal enterprise capacity, and analyzes their dynamic coupling logic to explain firms' transition from passive compliance to active low-carbon strategic layout.

Second, based on nine cross-industry sample enterprises, this paper identifies four

typical ESG transformation paths, and clarifies the trigger conditions, resource dependence, industrial adaptability and potential risks of each path via comparative case coding.

Third, this study constructs a multi-dimensional ESG strategic system matching differentiated transformation paths, and designs targeted strategic portfolios covering technological innovation, organizational governance, information disclosure and stakeholder collaboration.

### 3.2 Research Methodology

This study employs a mixed qualitative research framework integrating multiple case analysis, comparative research and textual analysis as its core methodological toolkit. Additionally, the study defines high-emission enterprises via three unified standards. First, industrial classification standard: enterprises belonging to thermal power, steel, petrochemical and other high-carbon statistical sectors. Second, emission intensity standard: enterprises whose carbon output per unit value is significantly higher than the industrial average level. Third, regulatory inclusion standard: key emission control entities incorporated into the national carbon emission trading market.

Such enterprises share four common industrial characteristics: fossil energy-locked production equipment with high transformation sunk costs; capital and technology-intensive renovation demands; extensive carbon spillover effects along upstream and downstream industrial chains; ESG transformation involves systematic upgrades of technology, assets and organizations rather than simple terminal pollution treatment.

A mixed qualitative study is carried out as follows: First, a theoretical sampling strategy is applied to select nine representative A-share listed firms spanning the power, steel and chemical sectors, with multi-source data including annual statements, ESG disclosures and industrial policy archives (2022–2024) triangulated to ensure empirical reliability; key observation indicators centering on ESG governance frameworks, carbon neutrality targets, low-carbon capital outlays and third-party ESG ratings are constructed for cross-firm evaluation. Second, multi-dimensional comparative analysis is conducted from cross-industry, intra-industry and financial correlation perspectives to unpack sectoral transformation disparities, firm-type strategic heterogeneities and the financial underpinnings of decarbonization investments. Complementarily, dual textual coding procedures are implemented: policy document coding identifies tiered green regulatory instruments under the dual-carbon agenda, while content analysis of corporate ESG reports and executive addresses decodes firms' latent low-carbon strategic orientations embedded in public disclosure discourse.

## 4 Industrial Background and Overview of Case Enterprises

### 4.1 Comparative Analysis of Transformation Background Across Three Industries

Power, steel and chemical industries contribute over 70% of China's total industrial carbon emissions, while their technical-economic characteristics lead to differentiated transformation logic. The power industry's carbon emissions mainly derive from coal combustion, with the core contradiction between national energy supply security and low-carbon asset upgrading. Its mainstream transformation path relies on wind-solar incremental expansion and functional transformation of stock coal-fired generating units.

The steel industry suffers from severe long-process carbon lock-in. Its transformation follows a progressive route: short-term energy efficiency optimization, medium-term electric furnace popularization and long-term hydrogen metallurgy technological breakthrough, and is closely linked to downstream green steel procurement demand.

The chemical industry features complex product chains and diversified carbon sources covering fuel, production process and purchased thermal power. Its transformation depends on three parallel approaches: green electricity/hydrogen substitution, bio-based raw material upgrading and industrial park circular symbiosis, with huge cross-industry collaborative emission reduction space.

**4.2 Overview of Nine Case Enterprises**

Three typical listed enterprises are selected from each high-emission industry as research samples:

Power industry: Datang Power Generation (structural reshaping representative), GD Power Development (compliance governance benchmark), Huaneng Power International (pioneer of global transition bonds).

Steel industry: Baoshan Iron & Steel (technological breakthrough leader), HBIS Group (value chain synergy practitioner), Valin Steel (compliance-oriented local SOE).

Chemical industry: Wanhua Chemical (process innovation leader), Hualu Hengsheng (park circular economy model), Sinopec (full industrial chain integrated enterprise).

All nine sample enterprises continuously released complete ESG or social responsibility reports from 2022 to 2024, providing consistent and comparable data support for cross-case comparative analysis.

**4.3 Identification and Characterization of Four Typical ESG Transformation Paths**

**4.3.1 Technology Breakthrough Path**

**4.3.1.1 Path Characteristics and Driving Mechanism**

The core logic of the technology breakthrough path is to realize source decarbonization via sustained high-intensity R&D investment and disruptive low-carbon process innovation, replacing passive terminal pollution control and constructing long-term industrial green competitive barriers.

Endogenous driving forces include management's long-term low-carbon strategic cognition, stable operating cash flow supporting large-scale R&D expenditure and mature internal innovation organizational systems. Exogenous driving forces consist of tightening industrial energy intensity limits, inter-firm green technology competition and national low-carbon demonstration project subsidies. The primary restriction of this path lies in long R&D cycles and high technical trial risks, which is only applicable to industry leaders with stable long-term profitability.

**4.3.1.2 In-Depth Case Analysis: Baosteel and Wanhua Chemical**

Baosteel and Wanhua Chemical are typical representatives of the technology breakthrough path. Both firms maintain sustained large-scale R&D investment even during industrial profit downturns, forming positive cycles of technological innovation and ESG performance improvement. Table 1 and Table 2 display their core profitability indicators from 2022 to 2024.

Table 1 Analysis of Profitability Factors of Baosteel

| Baosteel | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 3677.78 | 3445.00 | 3221.16 |
| Net Profit Attributable to Parent (CNY bn) | 121.87 | 119.44 | 73.62 |
| Weighted Average ROE (%) | 6.33 | 6.01 | 3.65 |
| Cash Flow from Operating Activities (CNY bn) | 447.20 | 253.00 | 277.40 |
| Total R&D Investment (CNY bn) | 31.68 | 34.19 | 37.79 |

Source: Baosteel Corporation's 2022-2024 Annual Report

Table 2 Analysis of Profitability Factors of Wanhua

| Wanhua Chemical | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1655.65 | 1753.61 | 1820.69 |
| Net Profit Attributable to Parent (CNY bn) | 162.34 | 168.16 | 130.33 |
| Weighted Average ROE (%) | 22.75 | 20.42 | 14.29 |
| Cash Flow from Operating Activities (CNY bn) | 363.40 | 268.00 | 300.50 |
| Total R&D Investment (CNY bn) | 34.20 | 40.81 | 45.50 |

Source: Wanhua Chemical's 2022-2024 Annual Report

As shown in Table 1, Baosteel's profitability declined continuously from 2022 to 2024 under cyclical industry pressure, yet its annual R&D expenditure maintained steady growth and reached CNY 3.779 billion in 2024. The firm took the lead in putting a million-ton hydrogen-based shaft furnace into operation at Zhanjiang base, realizing milestone zero-carbon metallurgy technological breakthroughs. Meanwhile, Baosteel built an industrial AI intelligent manufacturing platform to precisely control production energy consumption, achieving a 6.1% year-on-year decline in carbon emission intensity in 2024. It has maintained CDP Climate A- Leadership rating and ranked first in China's listed firms' dual-carbon evaluation for three consecutive years.

Table 2 reflects Wanhua Chemical's stable profitability resilience. Its 2024 R&D investment hit CNY 4.55 billion, maintaining a year-on-year growth rate over 11%. The enterprise relies on iterative optimization of core MDI and TDI production processes to reduce unit energy consumption, while deploying photovoltaic, offshore wind and nuclear power projects to expand green electricity supply. Wanhua independently realized the industrialization of POE and high-end new materials, opening up new low-carbon growth curves beyond traditional polyurethane business. Table 3 further sorts out the two firms' comprehensive ESG rating performance.

Table 3 ESG Rating Performance Analysis of Two Companies

| Company | Rating / Honor | 2022 | 2023 | 2024 |
|---|---|---|---|---|
| Baosteel | S&P CSA Rating | Unavailable | Top 5% globally in industry | Top 5% globally in industry |
| Baosteel | S&P / Moody's / Fitch Rating | A-/A2/A+ | A-/A2/A+ | A-/A2/A |
| Baosteel | Central SOE ESG Pioneer Index | Ranked 4th | Included | Included |
| Baosteel | China Listed Company Dual Carbon Leadership | Excellent (Ranked 1st) | Excellent (Ranked 1st) | Excellent (Ranked 1st) |
| Baosteel | CDP Climate Change Rating | Unavailable | Leadership level (A-) | Leadership level (A-) |
| Baosteel | Fortune World's Most Admired Companies | Included | Included (No.1 in Metals) | Unavailable |
| Wanhua Chemical | Global Top 50 Chemical Companies Ranking | 17th | 18th | 16th |
| Wanhua Chemical | Lianhe Credit Rating | AAA/Stable | AAA/Stable | AAA/Stable |
| Wanhua Chemical | China Listed Company Dual Carbon Leadership | Unavailable | Excellent (Ranked 1st) | Unavailable |
| Wanhua Chemical | Central SOE ESG Pioneer 100 Index | Unavailable | Four-and-a-half-star level | Unavailable |
| Wanhua Chemical | ESG Best Practice / Pioneer Award | Included | Included | Included |

Source: Baosteel, Wanhua Chemical's 2022-2024 Annual Report, ESG Report

### 4.3.2 Structural Reshaping Path

#### 4.3.2.1 Path Characteristics and Driving Mechanism

The structural reshaping path refers to fundamental strategic adjustment of corporate asset portfolios, which drastically reduces the proportion of high-carbon thermal power assets and expands large-scale zero-carbon wind and photovoltaic layout, realizing complete redefinition of enterprises' profit composition and market positioning.

Endogenous constraints include massive upfront capital expenditure, short-term asset impairment risks and talent structure adjustment pressure. Exogenous supporting conditions cover national new energy industrial policies, continuous cost reduction of wind-solar equipment and diversified green & transition bond financing channels. This path is the dominant transformation mode for large traditional power conglomerates.

#### 4.3.2.2 In-Depth Case Analysis: Datang Power Generation

Datang Power Generation is the typical sample of the structural reshaping path. Table 4 displays its financial performance from 2022 to 2024.

Table 4 Analysis of Profitability Factors of Datang

| Datang | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1168.28 | 1224.04 | 1234.73 |
| Net Profit Attributable to Parent (CNY bn) | -4.07 | 13.67 | 45.06 |
| Weighted Average ROE (%) | -6.21 | -1.03 | 10.44 |
| Cash Flow from Operating Activities (CNY bn) | 204.60 | 212.40 | 261.20 |

Source: Datang's 2022-2024 Annual Report

In 2022, surging coal prices caused Datang a net loss of CNY 407 million, but the enterprise still persisted in large-scale new energy investment. Driven by continuous asset layout adjustment, its net profit rebounded sharply to CNY 4.506 billion in 2024, with wind and photovoltaic sectors becoming core profit contributors. Table 5 lists its core ESG operational indicators.

Table 5 ESG Rating Performance Analysis of Datang

| Evaluation Dimension | 2022 | 2023 | 2024 |
|---|---|---|---|
| Clean Energy Installed Capacity (%) | 33.10 | 37.75 | 40.37 |
| Coal Consumption for Power Supply (g/kWh) | Unavailable | 294 | Unavailable |
| Ultra-low Emission Units Capacity (%) | Unavailable | 98.8 | Unavailable |
| Included in ESG Index | Unavailable | Central SOE ESG Pioneer 100 Index | Central SOE ESG Pioneer 100 Index |
| SSE Information Disclosure Rating | Unavailable | Unavailable | A rating |
| Listed Company Honor | Unavailable | Unavailable | Golden Bull Award "Golden Information Disclosure Award" |

Source: Datang's 2022-2024 Annual Report, ESG Report

From 2022 to 2024, Datang's clean energy installed capacity ratio rose from 33.10% to 40.37%. Meanwhile, the firm promoted the three linked transformations of energy-saving, flexibility and heating renovation for coal-fired units, balancing national energy supply stability and low-carbon asset upgrading. Digital intelligent inspection systems further reduced operational energy consumption, and the enterprise obtained Grade A information disclosure rating on the Shanghai Stock Exchange in 2024.

### 4.3.3 Value Chain Collaborative Path

#### 4.3.3.1 Path Characteristics and Driving Mechanism

The core feature of the value chain collaborative path is to extend the boundary of corporate ESG governance to upstream and downstream industrial chains, and realize systematic low-cost emission reduction via full-life-cycle

carbon footprint management, green supply chain assessment and industrial park circular symbiosis.

Endogenous advantages include integrated industrial layout and stable long-term operating cash flow. Exogenous incentives originate from ISSB and GRI Scope 3 disclosure mandatory requirements, downstream green procurement standards and national circular economy policy subsidies. Collaborative emission reduction can effectively lower the marginal decarbonization cost compared with independent enterprise technological renovation.

#### 4.3.3.2 In-Depth Case Analysis: Hualu Hengsheng, HBIS and Sinopec

Three enterprises from chemical, steel and full-chain energy industries are selected as samples of the value chain collaborative path. Table 6, Table 7 and Table 8 respectively present their profitability data.

Table 6 Analysis of Profitability Factors of Hualu

| Hualu | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 302.45 | 272.60 | 342.26 |
| Net Profit Attributable to Parent (CNY bn) | 62.89 | 35.76 | 39.03 |
| Weighted Average ROE (%) | 25.58 | 12.81 | 13.05 |
| Cash Flow from Operating Activities (CNY bn) | 69.99 | 47.15 | 49.68 |

Source: HBIS's 2022-2024 Annual Report

Table 7 Analysis of Profitability Factors of HBIS

| HBIS | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1434.70 | 1227.44 | 1216.17 |
| Net Profit Attributable to Parent (CNY bn) | 13.95 | 10.84 | 7.07 |
| Weighted Average ROE (%) | 2.64 | 1.72 | 0.93 |
| Cash Flow from Operating Activities (CNY bn) | 92.35 | 112.10 | 96.78 |

Source: HBIS's 2022-2024 Annual Report

Table 8 Analysis of Profitability Factors of Sinopec

| Sinopec | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 33181.00 | 32122.15 | 30745.62 |
| Net Profit Attributable to Parent (CNY bn) | 670.82 | 604.63 | 503.13 |
| Weighted Average ROE (%) | 8.57 | 7.59 | 6.19 |
| Cash Flow from Operating Activities (CNY bn) | 1163.00 | 1615.00 | 1494.00 |

Source: Sinopec's 2022-2024 Annual Report

Hualu Hengsheng relies on coal chemical flexible co-production platforms to build internal park material and energy circulation systems, maintaining an asset-liability ratio below 30% for a long time, and extends industrial chains to high-value new energy materials to reduce unit carbon intensity. HBIS raised the procurement proportion of top five strategic suppliers to 82.72% in 2024, and developed low-carbon automotive steel to realize downstream collaborative emission reduction. Sinopec owns a full oil-gas-chemical industrial chain, with 2024 operating cash flow reaching CNY 149.4 billion to support cross-industry low-carbon layout. Table 9 summarizes the three firms' ESG governance and rating conditions.

Table 9 ESG Rating Performance Analysis of Three Companies

| Evaluation Dimension | Hualu Hengsheng | HBIS | Sinopec |
|---|---|---|---|
| ESG Report Disclosure | Continuously published, available on parent company Hualu Holding's official website | 2023 ESG report disclosed simultaneously with annual report | Continuously publishes sustainability reports |
| ESG Rating (2024) | Industry leading level | Huazheng B, Wind BB | Mid-to-upper level among mainstream ratings |
| Governance Structure | Incorporated into parent Hualu Holding's ESG management system | Established ESG management structure at the board level | Established a Sustainable Development Committee |
| Information Disclosure Rating | Unavailable | SSE Information Disclosure A rating (2024) | Received A rating for many consecutive years |
| ESG Improvement Measures | Parent company set up an ESG report section, subsidiaries disclose on an annual basis | Starting from 2024, preparing more detailed ESG reports and disclosing simultaneously with annual reports | First time developing a market value management system, incorporating ESG considerations |

Source: Hualu Hengsheng, HBIS, Sinopec's 2022-2024 Annual Report, ESG Report

### 4.3.4 Compliance-Oriented Path

#### 4.3.4.1 Path Characteristics and Driving Mechanism

The compliance-oriented path takes meeting regulatory carbon market settlement and stock exchange ESG disclosure rules as primary objectives. Enterprises under this path focus on constructing standardized carbon accounting ledgers and perfecting ESG reporting systems, and adopt low-risk, short payback-period energy-saving renovation as major transformation measures.

External rigid constraints include carbon quota compulsory fulfillment and listed firms' disclosure supervision requirements. Internal characteristics include limited R&D budget, fluctuating profitability and incomplete long-term low-carbon strategic layout, which makes this path the mainstream starting mode for most local state-owned high-emission enterprises.

#### 4.3.4.2 In-Depth Case Analysis: Valin Steel, GD Power, Huaneng International

Valin Steel, GD Power and Huaneng International are three compliance-oriented sample enterprises. Table 10, 11, 12 list their financial indicators respectively.

Table 10 Analysis of Profitability Factors of Valin

| Valin | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1686.36 | 1644.65 | 1446.84 |
| Net Profit Attributable to Parent (CNY bn) | 63.78 | 50.78 | 20.31 |
| Weighted Average ROE (%) | 13.42 | 9.87 | 3.81 |
| Cash Flow from Operating Activities (CNY bn) | 94.57 | 52.73 | 57.78 |

Source: Valin Steel's 2022-2024 Annual Report

Table 11 Analysis of Profitability Factors of Guodian

| Guodian | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1946.74 | 1809.98 | 1791.82 |
| Net Profit Attributable to Parent (CNY bn) | 28.21 | 56.08 | 98.31 |
| Weighted Average ROE (%) | 6.07 | 11.83 | 18.59 |
| Cash Flow from Operating Activities (CNY bn) | 377.40 | 425.80 | 556.40 |

Source: Guodian Electric Power's 2022-2024 Annual Report

Table 12 Analysis of Profitability Factors of Huaneng

| Huaneng | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 2467.24 | 2543.96 | 2455.50 |
| Net Profit Attributable to Parent (CNY bn) | -73.87 | 84.45 | 101.35 |
| Weighted Average ROE (%) | -18.50 | 11.25 | 13.14 |
| Cash Flow from Operating Activities (CNY bn) | 325.20 | 455.00 | 505.30 |

Source: Huaneng International's 2022-2024 Annual Report

Valin Steel released its first complete sustainability report in 2024 in response to Shenzhen Stock Exchange rules, and adjusted the board committee structure to add ESG management functions. GD Power maintained stable profit growth year by year, continuously optimizing standardized ESG disclosure mechanisms and retaining Grade A disclosure rating. Huaneng International, as the world's first issuer of transition bonds, complies with

dual A+H listing disclosure rules, and translates compliance advantages into low-cost green financing channels. Table 13 compares their ESG governance performances.

Table 13 ESG Rating Performance Analysis of Three Companies

| Evaluation Dimension | Valin Steel | GD Power | Huaneng Power International |
|---|---|---|---|
| ESG Report Disclosure | 5th annual sustainability report (released in 2024) | Continuously published social responsibility reports for many years | Continuously publishes sustainability reports |
| Governance Structure | Plans to rename the original Strategy Committee to Strategy and ESG Committee, no longer setting up a Supervisory Board | Established ESG management structure at the board level | Established a Sustainable Development Committee |
| ESG Rating | Ongoing progress | Mid-to-upper level within the industry | Mid-to-upper level among mainstream ratings |
| Information Disclosure Rating | SSE A rating (2024) | Continuously standardizes disclosure | Received A rating for many consecutive years |
| Regulatory Compliance Response | Starting from 2024, preparing more detailed ESG reports and disclosing simultaneously with annual reports | Responds to regulatory requirements such as HKEX | World's first transition bond issuer |

Source: Valin Steel, GD Power, Huaneng Power's 2022-2024 Annual Report, ESG Report

### 4.4 Cross-Case Comparative Analysis and Evolution Logic of Transformation Paths

The four transformation paths summarized in this paper are not mutually exclusive alternatives, but present clear progressive evolutionary relationships from basic to advanced levels. The compliance-oriented path is the essential foundation for all high-emission enterprises' ESG construction, completing standardized institutional frameworks and information disclosure systems. The value chain collaborative path represents the advanced evolution of compliance management, which reduces overall transformation costs through industrial upstream and downstream synergy. The structural reshaping path belongs to deep strategic adjustment via large-scale asset portfolio optimization. The technology breakthrough path is the top-tier transformation mode relying on proprietary low-carbon innovation to form irreplaceable industrial competitive barriers.

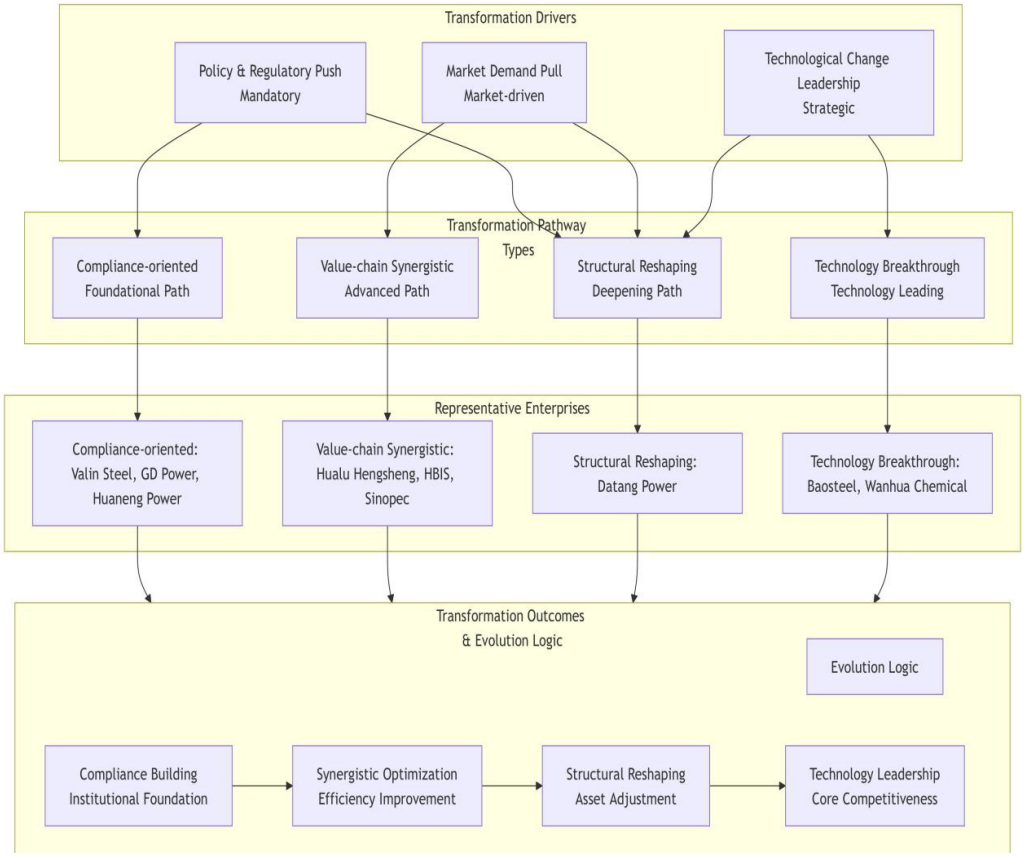


Figure 1 ESG Transformation Path Map

Industrial heterogeneity determines differentiated path matching rules. Steel and chemical industry leaders with sufficient R&D capacity tend to choose the technology breakthrough path, while mid-sized firms adopt value chain synergy strategies. Power enterprises generally take structural asset reshaping as the core transformation direction matched with compliance governance construction. Local small and medium high-emission enterprises with limited financial resources mostly start with the compliance-oriented path. In actual operational practice, most enterprises adopt mixed multi-path layouts with one dominant transformation mode.

## 5 Design of Differentiated ESG Strategic Systems Based on Transformation Paths

### 5.1 Four Core Strategic Dimensions

#### 5.1.1 Technological Innovation Strategy

Enterprises following different transformation paths hold differentiated technological investment priorities. Technology breakthrough firms need to maintain persistent high R&D intensity, carry out parallel layout of multiple low-carbon technical routes, and build industry-university-research collaborative platforms to disperse innovation risks, focusing on hydrogen metallurgy, CCUS and high-end green new material industrialization.

Structural reshaping power enterprises' technological investment concentrates on mature wind-solar storage equipment and coal-fired unit flexibility transformation, reducing trial-and-error costs of unproven cutting-edge technologies. Value chain collaborative firms prioritize park circulation technology and upstream-downstream coupled process renovation, sharing R&D expenditure via industrial alliance cooperation. Compliance-oriented enterprises only deploy mature short

payback-period energy-saving equipment to accumulate transformation funds before investing in disruptive low-carbon technologies.

**5.1.2 Corporate Governance and Organizational Change Strategy**

Governance mechanism design must match enterprises' dominant transformation path. Technology breakthrough firms establish independent R&D-ESG special committees, formulate long-term innovation incentive mechanisms, and bind executive compensation indicators with carbon intensity reduction and low-carbon patent output.

Structural reshaping enterprises build exclusive new energy investment decision groups and standardized high-carbon asset impairment evaluation systems to balance traditional thermal power and clean energy layout. Value chain collaborative enterprises extend ESG assessment mechanisms to supplier management, setting joint low-carbon working groups with upstream and downstream partners. Compliance-oriented enterprises prioritize perfecting board ESG functional departments and internal carbon accounting control procedures to fully satisfy regulatory bottom-line disclosure requirements.

**5.1.3 Information Disclosure and Stakeholder Communication Strategy**

Disclosure focus varies significantly among four types of enterprises. Technology breakthrough firms take quantified low-carbon patent data and demonstration project emission reduction effects as core disclosure content to convey long-term technical moat value to capital market investors.

Structural reshaping enterprises focus on releasing clean energy installed capacity proportion and new energy profit contribution indicators to display asset low-carbon optimization progress. Value chain collaborative enterprises emphasize full-life-cycle carbon footprint and supplier ESG assessment data to meet international standard Scope 3 disclosure demands. Compliance-oriented enterprises standardize all mandatory disclosure indicators first, and gradually add forward-looking carbon neutrality targets on the basis of meeting stock exchange supervision rules.

**5.1.4 Stakeholder Collaboration Strategy**

Stakeholder cooperation layouts correspond to transformation characteristics. Technology breakthrough enterprises cooperate with universities and research institutes to build joint low-carbon laboratories and share innovation costs. Structural reshaping power firms deepen coordination with local governments and green financial institutions to obtain new energy land and credit support. Value chain collaborative enterprises implement green supplier rating systems and jointly develop low-carbon products with downstream clients to build industrial sustainable alliances. Compliance-oriented enterprises maintain regular communication with regulators and institutional investors to mitigate climate compliance risks.

**5.2 Differentiated Strategic Combinations for Four Paths**

This study establishes four differentiated matched strategic portfolios corresponding to the four categorized corporate ESG transformation pathways derived from multi-case evidence, with clear scope of application delineated for each set of integrated strategies:

Technology breakthrough strategic portfolio: Composed of sustained high-intensity research and development input, R&D-centric ESG governance architecture, targeted disclosure of low-carbon technological achievements, and industry-university-research collaborative innovation mechanisms. This portfolio is designed for profitable industrial frontrunners that aim to build long-term differentiated green competitive moats via proprietary

decarbonization technologies.

Asset structural reshaping strategic portfolio: Integrated with large-scale investment in zero-carbon clean assets, dual-track risk governance covering both high-carbon legacy and emerging green assets, disclosure frameworks centering on energy mix metrics, and multi-stakeholder coordination with administrative authorities and financial intermediaries. It targets large incumbent energy conglomerates engaged in systematic asset portfolio decarbonization.

Value chain collaborative strategic portfolio: Incorporates industrial park circular economy retrofits, full-spectrum ESG oversight covering upstream and downstream supply chains, enterprise-wide full life-cycle carbon disclosure systems, and cross-factory synergy via industrial alliances. The strategic suite fits integrated steel and chemical enterprises possessing complete vertical industrial layouts.

Compliance-driven strategic portfolio: Centered on low-capital energy-saving technical renovations, standardized internal ESG control procedures, fundamental regulatory-mandated information disclosure, and routine communication mechanisms with institutional investors and industry regulators. This set of strategies applies to local state-owned enterprises constrained by insufficient financial resources that remain at the preliminary stage of low-carbon transition.

## 6 Conclusions and Implications

### 6.1 Main Research Conclusions

First, four typical categorized ESG transformation paths exist for domestic high-emission enterprises under dual-carbon constraints, namely technology breakthrough, structural reshaping, value chain collaboration and compliance orientation. The four paths follow a progressive development sequence, and enterprises' dominant transformation choice is jointly determined by industrial attributes, profitability and internal resource endowments.

Second, stable operating cash flow and sustained profitability constitute the fundamental financial foundation supporting all transformation modes. Technology breakthrough requires long-cycle continuous R&D expenditure; structural reshaping demands massive upfront new energy capital outlay; value chain synergy and compliance governance both rely on persistent environmental protection investment, and profit volatility will directly restrict enterprises' transformation depth.

Third, a positive feedback loop exists between ESG transformation performance and capital market feedback. Complete standardized low-carbon layout and high-quality information disclosure can lift corporate ESG ratings and reduce green financing costs, providing continuous financial support for subsequent low-carbon investment.

Fourth, industrial heterogeneity generates path differentiation effects. Power enterprises mainly adopt structural asset adjustment strategies; steel and chemical industrial leaders choose technological breakthrough paths, while mid-sized enterprises rely on industrial chain synergy; local small high-emission enterprises start transformation from compliance construction.

### 6.2 Theoretical Contributions

This paper integrates institutional theory and the resource-based view to construct the unified "dual carbon pressure-enterprise capability-ESG response" analytical framework, clarifying the interactive mechanism between external carbon regulatory pressure and enterprises' heterogeneous internal resources. Based on cross-industry multi-case comparative analysis, this study systematically distinguishes the characteristics, driving logic and applicable boundaries of four transformation paths, making

up for the research defects of single-industry and single-case literature, and expands the application scope of corporate sustainable governance theory under carbon neutrality targets.

**6.3 Practical Implications**

High-emission enterprises should abandon unified one-size-fits-all transformation templates and select matching dominant paths according to industrial positioning, R&D reserves and financial status. Industrial leaders with abundant funds can take the initiative to deploy forward-looking low-carbon technologies; large energy groups focus on clean asset substitution layout; integrated chain enterprises promote upstream-downstream collaborative emission reduction; profit-limited local enterprises prioritize compliance disclosure and short-cycle energy-saving renovation. All firms should establish long-term low-carbon investment budgets to balance short-term transformation costs and long-term green value appreciation.

From a policy design perspective, regulatory authorities should formulate differentiated industrial green policy portfolios tailored to the four categorized ESG transformation pathways identified in this research. Specifically, targeted R&D tax deductions and special subsidies for low-carbon demonstration projects shall be implemented for enterprises adopting the technology breakthrough path. For energy conglomerates pursuing asset structural reshaping, authorities may scale up the supply of green bonds and transitional credit facilities to ease capital expenditure pressures. For firms relying on industrial chain collaborative decarbonization, policymakers can support the construction of circular economy industrial zones and launch standardized green supply chain incentive frameworks. For local state-owned enterprises at the compliance-oriented transformation stage, systematic training programmes on carbon accounting specifications and normative ESG disclosure guidelines should be rolled out. Such tiered policy arrangements can eliminate one-size-fits-all rigid carbon emission reduction mandates imposed indiscriminately across all high-carbon industrial sectors.

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# Personalized Shopping Experience in Retail through Internet of Things-enabled Indoor Positioning and Real-time Product Recommendations*

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**Abstract:** The competitive pressures of e-shopping are compelling the retail industry to invest in more personalized and interactive shop to enhance networking experiences of customers. Customized recommendations, ease of navigation, and hassle-free shopping experience are emerging trends. Conversely, the conventional bricks-and-mortar stores find it difficult to offer these experiences due to limited physical tracking capabilities and generic marketing, which decreases customer engagement and cross-selling opportunities. To resolve this operational gap, this study proposes a smart store framework that integrates Internet of Things (IoT)-enabled indoor positioning system with real-time, data-driven product recommendations. This system uses the ultra-wideband (UWB) sensors and mobile tags placed in a retail space in order to track customer movement and gather accurate location-based behavioural data. The spatial data is then mined through the usage of association rule mining to extract highly confident purchasing patterns and generate personalized product recommendations based on essential yardsticks like support, confidence as well as lift. The paper presents a case study based on a real time supermarket scenario to show that the algorithm can effectively find the best complementary products in order to extract high and useful cross selling rules on the daily use products. Moreover, incorporating augmented reality (AR) technology offers proximity-based visualization that significantly enhances in-store navigation for the end user. In conclusion, a solution designed to improve customer convenience and satisfaction and enables retail management to utilize data and a scalable solution to optimize physical store layouts and implement highly targeted promotions to build long-term customer loyalty in a digital world.

**Keywords:** Internet of Things; Indoor Positioning; Augmented Reality; Association Rule Mining; Personalized Recommendation.

## 1 Introduction

The retail sector has undergone a major transformation in recent times due to rapid digitalisation, increasingly fierce competition, and changing customer expectations (Malenkov et al. 2021). No longer a mere product

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purchase, shoppers require speed, convenience, personalization, and an experience increasingly more than a purchase. The development of e-commerce was an additional element that raised the bar for product discovery, recommendation quality and convenience of service (Beyari, 2021). It is putting the physical retail stores under pressure to redesign their operations and customer experience. According to Islam et al., 2024, traditional store models dependent on product display and manual processes are increasingly losing effectiveness in attracting customers. Retailers have to explore new technologies and service models that would bridge the gap between physical and online shopping. The emergence of the consumer-centric nature has led to the keen demand for solutions offering real-time information, enhanced customer service, and personalized shopping experience.

Solutions use Internet of Things (IoT) technologies which are pivotal in capturing real-time data from the physical shopping environment (Hossain et al., 2021). Through sensors and connected devices, retailers can track the movement and dwell time of the customer, interaction with the product, shopping behavior inside the store (Jose et al., 2024) By means of getting such large amount of data, retailers will be able to analyze the shopping habits of the customers. As one of data mining techniques, Association rule mining helps to find relationships between products and discover items which are often bought together (Sinha, 2021). Recommendations for each customer according to their needs and context will be generated by applying association rules for customer behavior. Further relevant products will be suggested. The accuracy of recommendations improves as product promotion becomes more effective. By helping retailers optimize product placement, cross-selling opportunities and inventory planning, (Sri darshan et al., 2024).

In order to enhance the use and delivery of data analysis results, augmented reality (AR) can optimize customer experience by visualising routing information. After identifying customer preferences and product recommendations from data analytics, AR can direct customers on the best route to the relevant items in the store (Cruz et al., 2019). As a result, the recommendation results will be less complicated and easier to follow. This is especially useful in a large retail environment, where it is difficult to find product locations. By using a phone, or any other interactive tool instead of relying entirely on stationary maps or signage to assist with customers detouring (Cao et al., 2023). Augmented Reality (AR) displays product locations, aisles directions as well as nearby promotional information in a more intuitive way. AR has the capability to convert analytical results into actionable advice that aids the shopping process.

This research outlines a smart store framework that integrates indoor positioning with real-time and data-driven product recommendations. This framework makes use of ultra-wideband (UWB) sensors to identify customer locations and collect in-store movement data, which can then be personalized analysed and recommended. Association rules help in finding a relationship in products. It aids in the delivery of relevant product suggestions based on their preferences and shopping behaviour. AR technology is also integrated so that the routing information can be visualized to make it easier for customers to reach the suggested goods. The framework intends to improve product discovery, enhance navigation convenience and make shopping a more seamless and personalized journey through UWB, association rules and AR. The suggested framework is aimed at enhancing physical retail experience through data driven

and consumer centric innovation.

This paper is organized as follows. The review of literature relevant to physical retail environment, personalized shopping experience, IoT and data analysis, and AR application, is in section 2. Section 3 offers research methodology and framework design. Section 4 gives an example to show how the framework proposed will work in practice. Ultimately, Section 5 wraps up the article while discussing future implications.

## 2 Literature review

### 2.1 Challenges in Physical Retail Environments

Physical store continues to be an important format because it has certain benefits which cannot be fully replicated online. According to Pei et al 2020, one of the main advantages is direct staff input availability. When consumers are faced with choice overload, they require assistance in understanding the features of the product, comparing it with alternatives and choosing a product that suits them best. According to Ganesha et al. (2020), salespeople can offer instant recommendations and reasonable explanations which can help lessen the uncertainty and reduce the chance of post-purchase regret. Besides, physical stores give customers a direct feel of the products before purchase (Zhang et al., 2022). For instance, in supermarkets, buyers can inspect whether the fruits and vegetables are fresh, check competing brands, read nutrition labels, and inspect the product (An et al. 2021) Thanks to this benefit, in-store shopping is particularly beneficial for products for which visual inspection is important. Physical retail spaces' hallmark strength remains the face-to-face engagement and physical access to products.

The physical retail store does have its own challenges despite these advantages. The customers at such places as supermarkets, mall shops, specialized stores, largely suffer the disadvantage as they often have an issue finding the actual product which they want to buy. As a result, the customer's effective time spent to shop is reduced, negatively impacting the customer experience (Cruz et al., 2019). Many stores will offer signage and directional displays, but often those signs are hard to see and read. They also may be hard to update. Increasing operating costs are also troublesome for physical retailers. Such things happen mainly due to expensive rental expenses during the uncertain situation of unknown times. Due to the rapid growth of e-commerce, competition is increasing as sellers are more frequently offering quicker and interactive shopping experiences (Nitumba et al, 2023). Real-time data on consumers cannot be collected like online platforms can. Those are also unable to perform analysis. This makes it difficult to personalize their recommendations and assist with navigation. Technology adaptation will help surmount these limitations to enable in-store data collection and analysis and enhance customer's in-store shopping experience. The implementation of the most recent technologies including IoT and UWB will facilitate the collection of more authentic data regarding both the customers' behaviour while they are on floor as well as the product performance; (Gupta et al., 2024; Yan et al., 2026).

### 2.2 Internet of Things and Ultra-Wide Band

The IoT refers to the interconnection of several devices, sensors, and smart objects which can collect, exchange, and process the data through the internet (Kopetz & Steiner, 2022). These devices, including RFID tags, actuators, and other kinds of connected devices that enable real-time communication and automated decision-making. (Coito et a., 2021) The IoT provides a network that helps in identification, tracking, monitoring and managing the objects in different conditions (Anandhi et al., 2019). As such,

physical entities can become smart systems which generate useful information continuously. The use of IoT gives a shared infrastructure which in turn allows organizations to improve visibility, responsiveness and control over physical processes (Sallam and others, 2023).

IoT is getting more important in retail and other applied settings, as it allows for data collection directly from environments. This enables monitoring the movement of customers, interaction with products, and conditions of operations in real-time. (Pandey et al., 2025). This data could then be analyzed for the sake of better decision-making, service quality improvement and efficiency enhancement. Through IoT, firms enhance their methods by implementing personalized services, dynamic product proposals, and more. However, the usefulness of IoT, in general, highly depends on the accuracy and reliability of the data gathered. This is specifically for indoor settings where positioning and tracking are more difficult (Sattarian et al., 2019).

UWB technology is closely associated with indoor positioning due to its ability to accurately track locations in an indoor environment (Elsanhoury et al., 2022). As opposed to external environments, the internal environment has interference, reflection, blockage by walls, shuffling and other similar items (Waqas et al., 2024). The positioning of the components of the various pods and kiosks is complicated under these conditions. UWB solves this issue by employing large frequency bandwidth to support high-resolution ranging and localization (Zhao et al., 2021). It is therefore suitable to facilitate asset tracking and indoor navigation and retail analytics. When utilized with other sensors or digital systems, the accuracy of indoor positioning may further be improved with UWB, enhancing quality of location-based services (Hailu et al., 2025). UWB technology is essential for providing precise, efficient and convenient indoor positioning applications.

**2.3 Data-Driven Analysis using Association Rules Mining**

The physical shopping ecosystem is merged with UWB and IoT to derive data. Association rule mining can be deployed on this data to uncover meaningful relationships among products and customer behaviour (Chan & Gunawan, 2023). This method evaluates transaction patterns for identifying items which are purchased together frequently. It provides a systematic understanding of customers' shopping patterns (Ho et al., 2012). Thus, transforming raw data into useful information aids in improving performance and decision making.

Association rule mining is particularly useful in a retail setting as it uncovers hidden relationships among the objects purchased. For example, bread and butter, shampoo and conditioner, noodles and seasoning, a lot of times appear in the same basket. When retailers identify which products are associated with one another, they can then make better recommendations. The analysis does not make a general assumption but rather uses actual behavioral evidence gathered from the customer. Yudhistyra et al., (2020) used association rule mining in gold, silver, and precious metal trading company, to identify useful patterns of products sales. Babitha et al. (2024) applied association rule mining to find real or capability relationships amongst gadgets (products, offerings, customers, etc.) to understand how customers buy or use technology. Unvan (2021) conducted a market basket analysis through association rules to make installation of products operation in supermarkets and profit increase.

Essentially, association rules mining ensure that recommendations are more accurate and context aware, hence enabling personalization. Association rules can help retailers respond

more effectively to customer needs during the shopping journey when combined with real-time data obtained through IoT and UWB. Improved inventory planning, promotion design and store layout optimization can also be done through it. Consequently, association rule mining serves as a valuable analytical tool for converting large retail data into actionable insights for enhancing customer experience and operational performance.

### 2.4 Augmented Reality in In-Store Navigation

AR is an emerging technology that enhances the real-world environment with digital information in real time to create a more interactive experience (Sanni, 2024). In retail environments, AR can be leveraged to aid customers with in-store navigation, showing them where to find different products and other useful information via their mobile or smart-enabled interface (Xu et al., 2022). This facilitates shoppers navigating the store more efficiently and locating desired products with less effort. AR presents spatial information in a more intuitive way than traditional signs or printed maps.

Consumers can spend a long time looking for products in large retail environments such as supermarkets and department stores (Page et al., 2019). Shopping efficiency can be reduced, and the overall experience negatively affected. AR can assist in addressing this problem by converting route data into visual directions. For instance, given that a consumer has selected a product or received a recommendation, AR can indicate the route to the product location and guide the consumer through the store step by step (Chylinski et al., 2020). AR does not only enhance wayfinding but also minimizes search time and reduces physical exertion.

In addition, another advantage of AR is its ability to present information in context. AR technology can avoid requiring customers to read different instructions or interpret overwhelming maps. Instead, it can display arrows, markers or product labels in the users' direct field of view (Qiu et al., 2025). This ease of understanding makes the information more useful during the shopping process. Furthermore, AR can play a supporting role for other retail functions including promotional messages, product education to shoppers and interactive shopping assistance (Rejeb et al., 2023).

All in all, AR has great potential in-store navigation that makes the overall shopping experience better, interactive and personalised. AR can bring analytical insights to life for customers when integrated with location information and recommendation systems. As a result, it can effectively improve connection between digital intelligence and physical retail.

## 3 Methodology

### 3.1 Smart Store Framework Architecture and Experimental Setting

The experimental setting for this study was established within a large-scale cooperative physical supermarket located in Hong Kong. To achieve high-precision indoor tracking, the proposed framework utilizes a combination of IoT network protocols and UWB technology. UWB utilizes short radio pulses over a wide frequency band to measure distance with centimeter-level accuracy. This makes it highly suitable for confined, narrow-aisle retail environments where traditional signals, such as Wi-Fi or Bluetooth, often suffer from severe signal reflection, interference, and obstruction from dense shelving.

The hardware used here consists of ten ceiling mounted UWB anchor sensors. To optimize coverage space and ensure proper triangulation, these anchors are set at the ingress and egress (top of the beginning and end) of each store aisle. Through standard Power over Ethernet (PoE) infrastructure, the anchor

network is powered and synchronized to reduce operational latency. By scanning a QR code linked to an active mobile UWB tag (G-sensor attached) on their physical shopping carts, customers start the tracking framework. The mobile tag is a dynamic node that continuously transmits spatial data to the anchor sensors.

**3.2 Data Collection and Preprocessing Strategy**

To implement the recommendation engine, the system follows the implementation of a two-layer data collection of user profile and transaction data. When users first register with the centralised mobile app, they are required to input basic profiling details about themselves. These details include name, age, gender and the preferred category of shopping. This serves as the foundational user profile.

To the predictive modeling stage, the algorithmic simulation was done using a base data set of 70 distinct transactional records. To represent realistic purchasing behaviors in a supermarket context, the dataset features 13 distinct categories of essential items purchased daily: milk, bread, cereal, soft drinks, eggs, rice, noodles, meat, fruits and vegetables, chips, tissue, cleaning products and frozen food. During the preprocessing phase, this transactional data was converted to a binary matrix using one-hot encoding. Within this matrix, a Boolean value of 1 indicated the presence of an item in the transaction in question, while a 0 indicated its absence. This standardised formatting allows for processing to be done with machine learning libraries.

**3.3 Association Rule Mining and the Apriori algorithm**

For giving relevant personalized product recommendations corresponding to pre-processed spatial and transactional data, Association Rule Mining is adopted in this study. The Pandas data science extension was used to implement the Apriori algorithm within the Python programming language. The algorithm finds patterns that are likely to occur together in consumer transactions. The recommendation engine assesses which products go well together or, in other words, how likely an antecedent is to lead to a consequent through the application of three core probability metrics:

1. Support is the minimum frequency of occurrence of an itemset in the transaction database that the pair is then ignored if rare.

2. Confidence, which is the conditional probability or the probability of a customer buying an item (the consequent) given that he has already bought another item (the antecedent).

3. Lift is the correlation coefficient which checks that it's observed that the two items are sold more frequently than if it is based on purchased independently. As a result, it clarifies the coincidence purchase.

To filter out statistically insignificant anomalies and generate robust cross-selling recommendations, we calibrated the algorithm with a set of strict mathematical rules. In particular, we set a support of at least 0.65 and a confidence of at least 0.70. The user will be provided highly relevant product recommendations to curb notification fatigue and enhance the robustness of the recommendation system due to this statistical constraint.

**3.4 Augmented Reality Customer Interface**

The mobile application acts as the main digital touchpoint for the consumer and incorporates AR features to materialize the algorithmic backend. Shoppers can create digital lists on the interface, which then compares them to the store's actual stock. In particular, through the use of the smartphone's camera, the application displays AR navigation paths and offers automated product recommendations based on the user's location in aisles. To improve user engagement without using greater personnel, the interface

further includes AR gamification that offers users to scan promotional posters or join a tracking game to win digital rewards, and parking coupons.

### 3.5 System Execution and Network Resilience Testing

The smart retail framework operates in a sequence of four stages:

1. The user establishes a local link with the UWB anchor network via the shopping trolley QR code.

2. The backend checks the user's online shopping list with real-time inventory to generate a physical routing map aided by AR.

3. The UWB system will always know the user's location, and when the user is within any of the product zones, the Apriori association rules trigger, which pushes high confidence cross-selling recommendations directly on to the AR interface.

4. The app has a calculation function that automatically tallies virtual carts at checkout and feedback. After the purchase, product rating information is collected, which transmits transactional data into the database and helps to revise Apriori threshold values in the future.

The aforementioned methodology will incorporate the test of network resiliency and load balancing to secure this continuous flow. The framework pre-empts network failures by simulating a variety of scenarios. It also distributes traffic across servers, ensuring that system crash or delay of data transmission at the time of retail overload does not disrupt UWB tracking and AR system.

## 4 Illustrative Case Study

### 4.1 Baseline Dataset and Descriptive Statistics

Prior to the physical deployment of the proposed smart store framework, a baseline descriptive analysis was conducted on the transactional dataset to validate the functionality. The Transactional Matrix comprises 70 different consumer baskets of daily necessities dispensed on a high-density supermarket floor plan. Prior to the use of Apriori algorithm, a frequency distribution evaluation was made to map the support of independent items leveraged across the 13 major products. This structural profiling is critical in determining the density of the data and confirming that our data set reflects real-world retail velocity of a store.

The independent support frequency analysis showed that itemsets related to daily chores and fast-moving grocery items had the greatest baseline presence in the transaction pool. In particular, a baseline independent support of 0.8000 was discovered for cleaning supplies and fruits and vegetables, which appeared in 56 out of the 70 simulated consumer baskets. The support of "milk" holds at 0.7714 as it is. "Bread", "chips" and "tissues" each have an independent support of 0.7571. The lower bounds of the target data distribution consisted of lower frequency necessities like "meat" (0.6571) and "frozen food" (0.7143). Optimally encoding these raw counts into a one-hot encoded binary matrix allows the framework to carry out cross-selling discovery without operational misrepresentation due to biased independent support baselines.

### 4.2 Algorithmic Simulation Outcomes and Rules Analysis

After validating the dataset, the computational engine executed the Apriori pipeline. Limiting the extraction of rules to a minimum support of 0.65 and a minimum confidence of 0.70 extracted rules that are most economically significant and that do not occur by accident. The computed mathematical outcomes of the algorithm from the computer terminal are transcribed in the standard empirical distribution, as shown in Table 1.

Table 1. Apriori Algorithm Association Rule Outputs

| Variable | N | Mean | P10 | P50 | P90 | Std. Dev. |
|---|---|---|---|---|---|---|
| **Innovation Measures** | | | | | | |
| Patent Count | 90262 | 0.6342 | 0 | 0 | 2.0794 | 1.0560 |
| Citation | 90262 | 1.0540 | 0 | 0 | 4.3960 | 2.0140 |
| Cit/Pat | 90262 | 0.6493 | 0 | 0 | 2.7760 | 1.2180 |
| Exploitive Patent | 90262 | 0.1098 | 0 | 0 | 0 | 0.4386 |
| Explorative Patent | 90262 | 0.5099 | 0 | 0 | 1.7918 | 0.9444 |
| **Firm characteristics** | | | | | | |
| Firm Size | 90262 | 11.6785 | 8.9872 | 11.6073 | 14.5563 | 2.1943 |
| Leverage | 90262 | 0.1468 | 0.0030 | 0.0914 | 0.3658 | 0.1629 |
| Profitability | 90262 | 0.0082 | -0.1429 | 0.0411 | 0.1637 | 0.2218 |
| Age | 90262 | 3.0083 | 1.7918 | 2.9444 | 4.2767 | 0.9677 |
| **Country characteristics** | | | | | | |
| GDP per capita | 90262 | 9.8876 | 8.4151 | 10.0525 | 10.7007 | 0.8917 |
| Credit/GDP (%) | 90262 | 158.0111 | 79.3 | 143.6 | 332 | 78.2072 |
| Stock/GDP (%) | 90262 | 71.2522 | 34.5 | 66.7 | 110.5 | 34.2062 |

The parameters provided in Table 1 uncover important behavioral dependencies. The symmetrical baseline pairing between bread and milk, as indicated in rules 1 and 2, is seeing a lift of 1.1495. Although the lower lift is quite common, it indicates less mathematical dependence than a specialized category. Rules 3 and 4 show an asymmetrical behaviour. Customers who buy cereal have a confidence of 94.12% (Confidence = 0.9412) to buy milk. In contrast, milk buyers have a conditional probability of 88.89% of buying cereal. The correlation amongst items in two categories is significantly driving the placement of items mutually in each other's category as per lift parameter of 1.2200 which is strong and positive.

The most noteworthy operational rule that can be extracted is the presence of a bidirectional relationship between household paper goods and chemical sanitation items (Rules 5 and 6). The antecedent-consequent framework which maps the antecedent, "Tissues" to the consequent "Cleaning Supplies", has a joint support of 0.7286 (0.9623). What this means is that in 96.23% of the cases where the tissues were selected, the cleaning supplies were also selected independently. The inverse rule is given by rule 6. Its confidence is 0.9107. The unified lift score of 1.2028 proves mathematically that the probabilities of these items being chosen occurs together and not independently and this provides a good operational trigger for proximity marketing in real time.

### 4.3 Contextual Triggers and Dynamic Route Optimization

To evaluate the practical efficacy of these extracted rules within a physical space, an illustrative case study was conducted within a large-scale cooperative supermarket environment in Hong Kong. The physical floor plan was mapped into a coordinate matrix synchronized with the tracking backend. The customer journey begins at the entrance terminal, where the shopper scans the unique QR code on their assigned cart tag to bind their mobile session to the local UWB anchor matrix.

Upon application initialization, the user enters their predefined shopping criteria or targets. As depicted in Figure 1, the digital interface displays a comprehensive selection screen where the user builds their initial electronic shopping list. Once confirmed, the system backend instantly processes the list, maps the target product coordinates across the store layout, and projects an optimized static routing path onto the customer's display screen. This standard navigational path is designed to minimize structural wayfinding confusion by calculating the shortest distance through the aisles based exclusively on the initial input vector.


Figure 1 Customer-Facing Interface and Standard route Navigation

### 4.4 Dynamic Recommendation Triggers and Spatial Optimization

The core performance advantage of the proposed framework becomes apparent during active navigation. As the shopper propels the shopping cart along the calculated physical path, the cart's UWB mobile tag continuously broadcasts short radio pulses to the surrounding ten aisle anchors. The location server processes these signal bursts in real time, calculating the exact spatial coordinates of the cart relative to the physical store shelving.

When the system detects that the user's coordinate vector has entered a predefined spatial

zone and remained there past a specific dwell-time threshold (signaling browsing behavior), the backend invokes the active Apriori rule matrix. For example, as illustrated in the step-by-step optimization sequence in Figure 2, when a customer stands in the tissue aisle, the location server references Rule 5 (Tissues  Cleaning Supplies; Confidence = 0.9623).

Due to the conditional trust exceeding the operational threshold of the system, the dynamic recommendation window gets activated on the application of the customer immediately. If the buyer accepts the recommended cross-selling item, the backend dynamically recalculates the path matrix. Instead of making the customer seek the product manually, AR guides them with real-time directional signs over the physical aisle displays. It helps in recalibrating a frictionless map along the sanitation shelves.

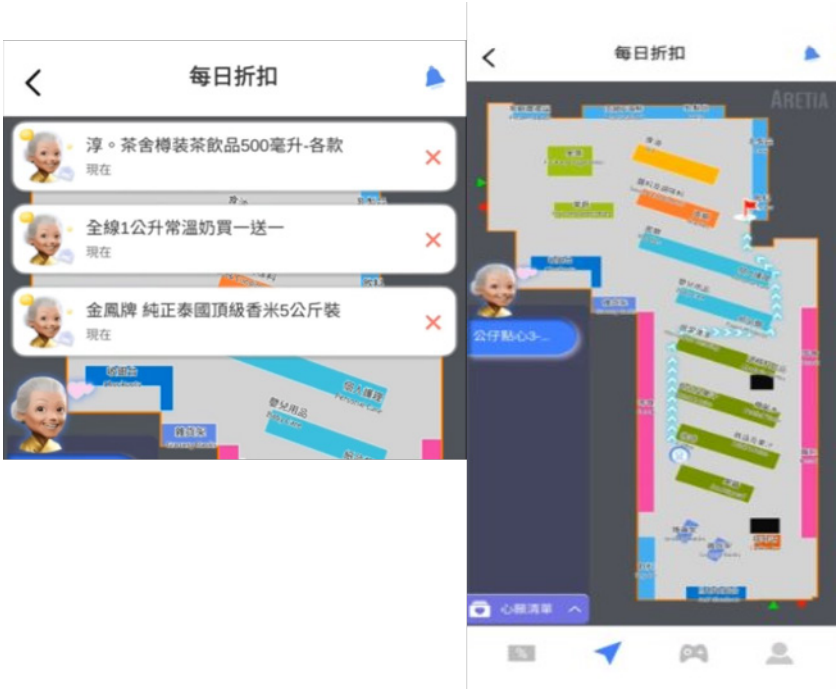


Figure 2  Dynamic Promotion Notification and Updated Route Optimization

**4.5 Transactional Closure and Closed-Loop Data Feedback**

The last section of the use case study maps checkout handling and data ingestion to close the operational loop. After a customer has traversed the optimized set physical layout, the mobile application performs an automatic calculation. As illustrated in the final image in Fig. 3, the digital interface counts the items in the cart, totals real-time promotional discounts and displays a full financial record to avert checkout-counter friction.

Post-purchase rating module is displayed on the user's interface after checkout verification. Consumers are asked to rate the items they purchased on a five-star scale and provide qualitative scores on satisfaction on the accurateness of the routing.  At this step, a system optimization occurs constantly. Up-to-date transaction records and satisfaction matrices are automatically relayed back to the main SQL database. Feeding this live data back into the proposed model enables the framework to dynamically change the Apriori Support and Confidence thresholds. Consequently, the retail matching engine automatically captures seasonal behavioural shifts of consumers. This signifies that unimportant alerts are discarded and

suggestions become precise with time.

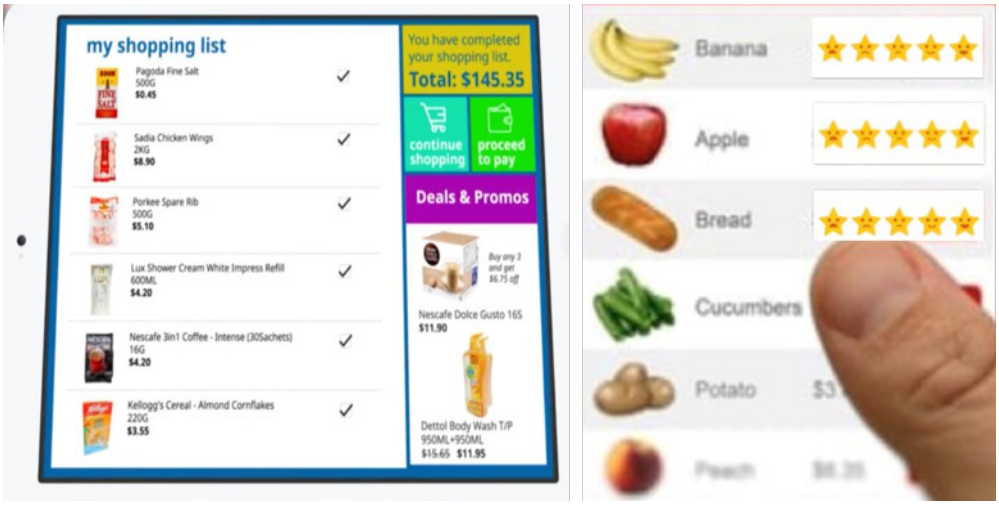


Figure 3. Automated Checkout and Post-Purchase Data Feedback Loop

## 5 Conclusion

Today's retail industry is undergoing a huge transition because competitive pressures from e-commerce and expectations from modern consumers are continuously changing. A robust smart store framework was introduced to facilitate the integration of physical retailing with the web-like customized shopping experience. The smart store framework was developed and tested in this study. The proposed system generates product recommendations based on real-time data utilizing IoT-enabled indoor positioning which successfully converts consumer movement in the physical world to sales intelligence.

The system uses a UWB tracking infrastructure to collect accurate spatial data at a centimeter level. The historical transaction database is processed using the Apriori machine learning algorithm to generate high probability purchase patterns. The presented algorithmic simulation shows how the framework properly identified essential cross-selling dependencies. For instance, one interesting pairing was the 96% conditional confidence between household paper goods and cleaning supplies. An interactive AR navigation interface effortlessly connected the consumer to mathematical relationships. In the end, this framework systematizes the personalization of physical shopping journeys for the consumer. Thereby, it reduces friction while offering retailers sales opportunities with high probability and relevant context.

### 5.1 Theoretical Contributions

This study is an important contribution to the literature on retail digitalization, spatial analytics, and consumer behavior prediction. Firstly, past scholarly articles have often studied Indoor Positioning System as well as Market Basket Analysis as technical disciplines separately. By integrating these areas of research, the current study advances literature by proposing a theory (Spatial-Transactional), which links physical movement with the probability of predictive purchasing. This framework goes beyond static post-purchase data mining and creates an active trigger mechanism which builds on context and executes algorithmically when two items are in physical proximity.

By presenting Augmented Reality not merely as a marketing gimmick, but as a cognitive aid, the study makes a further

contribution to Human-Computer Interaction literature on retail. Often, the high density of supermarkets can create complexity in the mind of consumers. The implementation of AR as the primary visualization tool offers an original concept for resolving these challenges. Furthermore, it transforms associations among the manifested data and tricky floor plans into visual-based routing commands. Most importantly, they effectively help to reduce the search time for the consumer.

**5.2 Managerial and Economic Implications**

The economic benefits of this IoT-enabled scheme will help overcome the most pressing challenges currently facing the retail sector such as rising physical operating costs, rents and need for differentiation. The guidelines significantly improve inventory management from backend managerial perspective with supply chain and inventory optimization. It allows store managers to make very tactical shelf-space allocations and dynamic replenishments by understanding exact co-occurrence probabilities (e.g., the one corresponding to tissues and sanitation goods is very high). The management may place items together for the convenience of the consumer if items are closely correlated. However, the management may choose to keep those items apart so that the consumer is routed through higher margin impulse buy areas using the AR navigational map. In addition, understanding these associations enables procurement teams to adjust supply chain orders accordingly. For example, if bread is on promotion, the consequent association indicates that orders for milk should also be increased.

The checkout closed loop data feedback mechanism guarantees that promotional budgets are not wasted on store-wide discounts anymore. Instead, capital for marketing is used only to target, high-probability individual offers with high ROI. Conversion probability is far higher when offers are pushed with the customer physically standing in the aisle as compared to the while using paper flyers.

The AR recommendation engine and the self-navigational routing map, by virtue of being automated, reduce the dependency of the retailer on sales staff for cross-selling and help in product discovery. Essentially, firms can redeploy their human resources from basic wayfinding assistance to customer service or complex management of inventories.

**5.3 Limitations**

While the proposed framework demonstrates significant economic and operational potential, certain implementation boundaries must be acknowledged. First, the physical deployment of an IoT-enabled network, including UWB anchors and mobile tags, requires initial capital investment and robust network infrastructure to process real-time spatial data effectively. Furthermore, physical constraints in specific retail environments, such as dense metal shelving, can induce signal reflection, requiring careful hardware calibration. Second, from a computational perspective, this study utilized a foundational dataset of 70 discrete transactions to validate the algorithmic proof-of-concept. Scaling this architecture to process tens of thousands of daily transactions will inherently increase the computational load. Additionally, association rule mining faces a standard "cold start" constraint, wherein newly stocked inventory items require a period of transaction accumulation before meeting the baseline support threshold for automated recommendation. Finally, as with any IoT architecture that captures continuous consumer data, large-scale deployment necessitates standard cybersecurity protocols to address data privacy and ensure robust consumer trust.

### 5.4 Future Research

In order to avoid excessive costs and space limitations of exclusive IoT deployment, future research must include spatial tracking algorithms with existing retail infrastructure. Analyzing the scope of sensor fusion particularly, fusing a UWB with sophisticated Wi-Fi arrays, Bluetooth Low Energy beacons and smartphone gyroscopes could lead to a drastic cut in the upfront installation costs.

Next, further empirical research should validate the framework with extensive, longitudinal datasets from a wide variety of store formats from hypermarkets to narrow-aisle convenience stores. This will provide the concrete evidence of whether the long-run benefits in cross-sell revenue and efficiency gains indeed outweigh the system maintenance costs over the years.

Future algorithmic research should ascertain the feasibility of integrating powerful Deep Learning models with the traditional Apriori algorithm from a computational perspective. The cold-start stock problem can be resolved by employing sequential pattern mining or neural collaborative filtering usage and development of tools for more elaborate consumer behaviour forecasting that takes seasonality, time of day and changing micro-economic trends into account.

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# The Dark Side of International Governance Reforms: Evidence from Corporate Innovation*

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**Abstract:** This study examines the impact of governance reforms on corporate innovation across 58 countries. We find that both the quantity and quality of innovation decline after board reforms, especially in explorative patents, suggesting that, in the context of these reforms, firms are more likely to focus on existing knowledge rather than exploring new ideas. The decline is stronger in countries with rule-based reforms, competitive industries, or high operational uncertainty. This supports the idea that stricter governance can lead to short-term thinking, which limits risky, long-term innovation. Our findings highlight the potential negative effects of international governance reforms on innovation.

**Keywords:** International Governance Reform; Corporate Innovation; Managerial Myopia
**JEL Classification:** G18; G34; O31

## 1 Introduction

Corporate governance has regained significant attention in both public and academic spheres following recent "governance crises."**. In response, many countries have implemented board reforms aimed at reducing agency costs. However, their impact on corporate performance remains unclear. This uncertainty stems from three factors: (1) Pre-reform board structures are endogenously chosen by firms as constrained optimal responses to governance issues***; (2) The complexity of corporate activities limits the efficacy of uniform reforms; and (3) Substantial heterogeneity across firms and countries complicates the evaluation of reform impacts (Hermalin and Weisbach, 2003; Adams et al., 2010).

Innovation is a critical driver of firm performance and national competitiveness, yet the effect of corporate government on innovation remains debated. Some studies argue that increased managerial oversight, such as greater institutional investor involvement, enhances innovation (Zhang et al., 2023; Xu et al., 2023; Luong et al., 2017; Aghion et al., 2013). Others suggest that greater scrutiny, such as shareholder litigation and analyst oversight, limits managerial flexibility, discourages risk-

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** "Governance crises" is an expression taken from Bebchuk and Weisbach (2010), which include the well-publicized scandals of Enron and WorldCom in 2012.
*** Theoretically, whether observed board structures can be interpreted as equilibrium or out-of-equilibrium phenomenon will lead to contrasting policy suggestions. Implementing regulations that impose restrictions on boards that are otherwise constrained optimal can be useless or even counterproductive in resolving corporate governance issues (Hermalin and Weisbach, 1998).

taking, and inhibits innovation (Chen et al., 2021; He and Tian, 2013). These conflicting findings may arise from differences in sample selection, time periods, or the trade-off between exploiting existing knowledge and exploring new technologies. For instance, firms tend to innovate more in familiar areas but remain cautious in high-risk exploratory fields (Balsmeier et al., 2017). To address these issues, a broader cross-country dataset and multidimensional innovation indicators are essential.

This study examines the impact of board reforms across 58 countries from 2000 to 2015, matching these reforms with the patent histories and financial data of publicly listed firms. We apply staggered difference-in-differences (DID) method, controlling for firm-specific and country-level characteristics. To address potential endogeneity, we conduct dynamic effects analysis to confirm the absence of pre-reform trends, and robustness checks using the stacked DID model yield consistent results. We also perform a parallel trend test to validate the results' validity. To capture various dimensions of innovation, we construct five patent-based indicators.

Our findings are as follows: (1) Board reforms led to a significant decline in both the quantity and quality of corporate innovation. Patent counts dropped by 18%, while patent citations and citations per patent fell by 26% and 15%, respectively. (2) The reforms dampened managerial incentives to explore new technologies, as evidenced by a smaller decline in exploitative patents compared to a 17% drop in explorative patents. (3) Rule-based reforms had more pronounced negative effects than “comply-or-explain” reforms. These effects were especially evident in competitive industries or firms facing operational uncertainty.

## 2 Related literature

The impact of board reforms on corporate innovation is complex and multifaceted. On one hand, traditional agency theory suggests that changes in board structure can improve oversight of management, reduce shirking, and limit self-interested behavior (Shleifer and Vishny, 1997; Fama and Jensen, 1983). This, in turn, can encourage managers to prioritize long-term projects, such as innovation, that benefit shareholders (Huang et al., 2023). On the other hand, innovation often involves long R&D cycles, high uncertainty, and significant risk of failure (Holmstrom, 1989). Recent studies suggest that stricter board governance may lead to short-term managerial behavior, reducing investment in innovation or promoting passive decision-making, which ultimately hinders innovation (Sierra-Morán et al., 2024; Islam and Rahman, 2023; Yuan et al.,2023; Faleye et al., 2011).

Countries adopt different board reform approaches, each with distinct impacts. Rule-based reforms, which impose mandatory governance structure, provide clear guidelines and can enhance corporate value (Liao, 2022; Fauver et al., 2017). However, their lack of flexibility may not be suitable for all industries or firms (Huang and Li, 2021). In contrast, "comply-or- explain" reforms offer flexibility, but may lead to selective compliance, weakening governance effectiveness (Orihara and Eshraghi, 2022). During crises, these reforms may reduce transparency and harm shareholder value (Ahmad and Akbar, 2023). Despite these insights, the effect of board reforms on corporate innovation remains unclear and underexplored in the existing literature.

## 3 Research design

### 3.1 Sample selection

We examine the impact of board reforms on corporate innovation using a sample of listed

companies from 58 countries between 2000 and 2015. To address potential outlier issues, we winsorize all continuous variables at the top and bottom 1% of the distribution. The variable sources, definitions, and construction details are described in Appendix A. Detailed information on board reforms across countries is given in Appendix B. Our sample includes 90,262 firm-year observations for 12,548 public firms.

**3.2 Definition of variables**

**3.2.1 Dependent variable**

Innovation: We collect patent data from the Worldwide Patent Statistical Database (PATSTAT), managed by the European Patent Office (EPO), and the OrbisIP database from Bureau van Dijk (BvD), a subsidiary of Moody's[****]. To avoid multiple recordings of the same invention, we identify only the first patent granted for each unique invention. We construct five firm-level patent indicators to measure the quantity and quality of innovation: Patent Count, Citations, Cit/Pat, Exploitative Patents, and Explorative Patents. Exploitative Patents reflect the extent to which a company's innovations build on its existing research directions, while Explorative Patents assess the degree to which a firm generates innovations using new information beyond its current knowledge base. Although explorative patents are generally riskier, they offer greater potential for advancing technological frontiers.

**3.2.2 Independent variables**

International Board Reforms: We developed a database of board reforms covering 58 countries, drawing information from sources such as Kim and Lu (2013), Fauver et al. (2017), the World Bank, European Bank for Reconstruction and Development (EBRD), and the European Corporate Governance Institute (ECGI). For each country, we recorded the year of the first reform and excluded countries without reforms. We then examined whether the reforms were rule-based and adhered to the "comply-or-explain" principle.

**3.3 Model**

We estimate the effect of board reform on corporate innovation using a staggered difference-in-differences approach following Bertrand and Mullainathan (2003). The baseline model is as follows:

$$Innovation_{i,j,\,c,t+1} = \alpha + \beta Post_{t-1} + \gamma X_{i,t-1} + \delta Z_{c,t-1} + \varphi_i + \varphi_{j,t} + \varepsilon_{i,j,c,t} \quad (1)$$

where $Innovation_{i,j,\,c,t+1}$ is one of the five measures of innovation defined above, and i, c, j, t indexes firm, country, industry, and year, respectively. We collect and use the information based on the first board reform adopted by a country, as it shall reflect a considerably sharp change in the corporate governance environment of the country for the first time. Postt−1 is equal to one for the years after a country has adopted the board reform, and zero otherwise. $X_{i,t-1}$ and $Z_{c,t-1}$are firm- and country-level variables, respectively. The firm-level controls are: Firm Size, Leverage, Profitability and Age. The country-level controls are: GDP, GDP per capita, and stock and credit market development. All of these country-year-level variables come from the Word Development Indicator (WDI) database via the World Bank. Detailed definitions of all the variables are presented in Appendix A. To mitigate unobserved time-invariant firm characteristics and time-varying industry heterogeneous features that might confound our results, we also introduce firm ($\varphi_i$) and industry-year ($\varphi_{j,t}$) fixed effects. Moreover, we cluster the error term at the country level.

**3.4 Summary Statistics**

Table 1 presents the summary statistics for our main variables. All patent-based variables are displayed in the natural logarithm form given

**** Prior studies on cross-country innovation tend to use R&D data or patent information from a single or a few largest patent offices, which may misrepresent certain key attributes (e.g., timing) of the innovation outcome.

they then to be right-skewed. In terms of the raw value, a firm on average develops 5 eventually-granted patents in a year, and receive 86 forward citations over the entire life of these patents, where each patent on average receives 5 forward citations. Moreover, the median size of a firm in our sample is about US$0.11 million. They have a leverage ratio of 0.15 and profitability ratio of 0.8% on average. Their median age since establishment is 19 years. Variables definition and construction are given in Appendix A.

Table 1 Summary Statistics

This table contains the summary statistics of the variables used in the main analysis. It shows the pooled statistics at firm-year level.

| Variable | N | Mean | P10 | P50 | P90 | Std. Dev. |
|---|---|---|---|---|---|---|
| **Innovation Measures** | | | | | | |
| Patent Count | 90262 | 0.6342 | 0 | 0 | 2.0794 | 1.0560 |
| Citation | 90262 | 1.0540 | 0 | 0 | 4.3960 | 2.0140 |
| Cit/Pat | 90262 | 0.6493 | 0 | 0 | 2.7760 | 1.2180 |
| Exploitive Patent | 90262 | 0.1098 | 0 | 0 | 0 | 0.4386 |
| Explorative Patent | 90262 | 0.5099 | 0 | 0 | 1.7918 | 0.9444 |
| **Firm characteristics** | | | | | | |
| Firm Size | 90262 | 11.6785 | 8.9872 | 11.6073 | 14.5563 | 2.1943 |
| Leverage | 90262 | 0.1468 | 0.0030 | 0.0914 | 0.3658 | 0.1629 |
| Profitability | 90262 | 0.0082 | -0.1429 | 0.0411 | 0.1637 | 0.2218 |
| Age | 90262 | 3.0083 | 1.7918 | 2.9444 | 4.2767 | 0.9677 |
| **Country characteristics** | | | | | | |
| GDP per capita | 90262 | 9.8876 | 8.4151 | 10.0525 | 10.7007 | 0.8917 |
| Credit/GDP (%) | 90262 | 158.0111 | 79.3 | 143.6 | 332 | 78.2072 |
| Stock/GDP (%) | 90262 | 71.2522 | 34.5 | 66.7 | 110.5 | 34.2062 |

## 4 Empirical results

### 4.1 Validity

It is essential to ensure that the governance reforms are not adopted for reasons associated with corporate innovation activities so that the comparative exogeneity of the reforms hold with respect to our construct of interest. Specifically, we use the following specification to examine whether pre-reform innovative activities in a country may predict the reforms to be initiated on the board.

$$Reform_{c,t} = \alpha_0 + \beta \times \text{Innovation}_{c,t\text{-}1} + \gamma X'_{c,t-1} + \delta_c + \delta_t + \varepsilon_{c,t} \quad (2)$$

We use a lag of one year for all patent-based measures at the country level, which is aggregated based on the average patent-

based metrics at the firm level. Reformc,t is an indicator variable set equal to one if a country c has already passed the board reform as of year t. We add the same set of country attributes which are used in baseline model to control for time-varying economic and financial conditions. These characteristics are GDP per capita, and stock market and credit market development. We also control for country fixed effects and year fixed effects to eliminate the impact of unobserved firm heterogeneity and macro shocks in the same year.

Table 2 shows that all innovation metrics are statistically insignificant, indicating no systematic differences in innovation trends between reforming and non-reforming countries before the reform.

Table 2 Pre-exiting Innovation Activities and Board Reform

This table shows the estimated effect of innovation activities prior to the first board reforms on the initiation of the reforms. Patent Count, Citation, Cit/Pat, Exploitive Patent and Explorative Patent are one-year lagged patent-based measures of innovation aggregated at country level. Reform is an indicator variable equal to one if the first board reform has been initiated as of a certain year. Control variables include GDP per capita, Credit/GDP and Stock/GDP, all measured with one-year lag. Country fixed effects and year fixed effects are included in the regressions. Robust standard errors clustered at the country level are reported in parentheses.

| **Dependent Var.** | **Reform** | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Patent Count | -0.0227 | | | | |
| | (0.043) | | | | |
| Citation | | -0.0161 | | | |
| | | (0.011) | | | |
| Cit/Pat | | | -0.0204 | | |
| | | | (0.013) | | |
| Exploitive Patent | | | | -0.0494 | |
| | | | | (0.072) | |
| Explorative Patent | | | | | -0.0164 |
| | | | | | (0.044) |
| Country Control | Y | Y | Y | Y | Y |
| Country FE | Y | Y | Y | Y | Y |
| Year FE | Y | Y | Y | Y | Y |
| Observations | 593 | 593 | 593 | 593 | 593 |
| Adjusted R-squared | 0.566 | 0.569 | 0.568 | 0.566 | 0.565 |

**Notes:** The t-statistics are provided in parentheses. The symbols *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively.

### 4.2 Baseline regression

Table 3 shows the baseline results. After the implementation of board reforms, both the quantity and quality of innovation decline significantly. In terms of innovation strategies, the number of explorative patents decreases by about 17%, while exploitative patents remain mostly unchanged. This suggests that board reforms tend to hinder firms' abilities to conduct innovation that relies more on the exploration of new knowledge. Overall, the results indicate that increased oversight of executives' performance induces managers to focus more on short-term gains, reducing investment in long-term, high-risk innovation projects.

Table 3 Board Reform and Corporate Innovation

This table presents the baseline results on the effect of the first board reforms on the innovative activities measured at firm level. Post is the key explanatory variable, which is equal to one after a country passes the first board reform, and zero otherwise. The dependent variable is one of the five patent-based measures of innovation, namely, Patent Count, Citation, Cit/Pat, Exploitive Patent and Explorative Patent, all measured as the natural logarithm of one plus the raw measure. All Control variables enter the regressions with a one-year lag. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses.

| Dependent Var | Patent Count | Citation | Cit/Pat | Exploitive Patent | Explorative Patent |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Post | -0.1804*** | -0.2648*** | -0.1450*** | -0.0117 | -0.1692** |
| | (0.056) | (0.080) | (0.044) | (0.014) | (0.071) |
| Firm Size | 0.0625*** | 0.0754*** | 0.0349** | 0.0155*** | 0.0531*** |
| | (0.021) | (0.027) | (0.014) | (0.003) | (0.018) |
| Leverage | -0.0564*** | -0.0759** | -0.0247 | -0.0067 | -0.0411* |
| | (0.016) | (0.036) | (0.026) | (0.007) | (0.021) |
| Profitability | 0.0639 | 0.1182** | 0.0637** | 0.0038 | 0.0659* |
| | (0.041) | (0.059) | (0.031) | (0.009) | (0.034) |
| Age | 0.0423 | -0.0021 | -0.0383 | 0.0134 | 0.0127 |
| | (0.040) | (0.060) | (0.027) | (0.014) | (0.035) |
| GDP per capita | 0.3997*** | 0.9347*** | 0.4976*** | 0.1712*** | 1.1029*** |
| | (0.146) | (0.175) | (0.109) | (0.035) | (0.075) |
| Credit/GDP | -0.0029** | -0.0052** | -0.0031** | -0.0005 | -0.0029** |
| | (0.001) | (0.002) | (0.001) | (0.000) | (0.001) |
| Stock/GDP | 0.0008 | -0.0014 | -0.0007 | -0.0002 | -0.0002 |
| | (0.001) | (0.002) | (0.001) | (0.000) | (0.001) |

| Dependent Var | Patent Count | Citation | Cit/Pat | Exploitive Patent | Explorative Patent |
|---|---|---|---|---|---|
| Firm FE | Y | Y | Y | Y | Y |
| Industry-Year FE | Y | Y | Y | Y | Y |
| Observations | 90,262 | 90,262 | 90,262 | 90,262 | 90,262 |
| Adjusted R-squared | 0.730 | 0.598 | 0.452 | 0.743 | 0.689 |

Notes: The t-statistics are provided in parentheses. The symbols *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively.

Recently, the conventional staggered DID approach has been criticized for potential biases caused by time-varying and heterogeneous treatment effects (Baker et al., 2022). To address this issue, we adopt the method of Cengiz et al. (2019), constructing a stacked sample at the firm-year level. Each treated country undergoing a board reform is matched with control countries that have not yet implemented a board reform within the [-8, +8] years around each reform. These matched observations form a single cohort, and we apply a stacked DID model to estimate the effects. The stacked DID results align with the baseline model, supporting the robustness of our conclusions. Detailed results are provided in Appendix C.

### 4.3.Dynamic Analysis

By tracing the changes of innovation around the reforms over time, we can assess whether there are any systematic differences between corporate innovative activities of the firms in the years prior to the reforms, and whether omitted variables other than the board reforms could have influenced subsequent innovation. Thus, we conduct a dynamic analysis by introducing a battery of year dummies into the baseline model. The dynamic analysis equation is as follows:

$$Innovation_{i,c,t+1} = \alpha_0 + \alpha_1^{\tau} \sum_{\tau=-4}^{4} D_{c,t}^{\tau} + \gamma X_{i,t-1} + \delta Z_{c,t-1} + \delta_i + \delta_{j,t} + \varepsilon_{c,t} \quad (3)$$

where $Innovation_{i,c,t+1}$ is one of the five patent-based proxies for innovation measured one year ahead, and i, c, j, t indexes firm, country, industry, and year, respectively. Dc,tτ is the collection of time dummies defined around the year of board reform. It is set equal to one in a year if a country adopted the board τ years ago ( τ>0) or will adopt the reform in τ years (τ<0), and zero otherwise. $D_{c,t}^{0}$ is equal to one in the year of the reform. $D_{c,t}^{4}$ is equal to one if a country has adopted the board reform for four or more years. We add the full set of control variables of the baseline model to control the characteristics at firm-level and country-level over time. We also control the time-invariant country attributes, and potential industry trends or contemporaneous changes of global industry environment using country and industry-year fixed effects, respectively. Again, we cluster the standard errors at the country level to address the concern that innovations within a country might be intercorrelated under the same regime.

Table 4 shows a significant decline in innovation starting in the second year after the reform, with no upward trend observed before the reform. This suggests that our results are unlikely driven by pre-reform innovation trends or unobserved factors, mitigating reverse causality concerns.

Table 4 Board Reform and Corporate Innovation: Dynamic Changes

This table presents the dynamic changes in innovative activities at firm-year level around the initiation of the first board reforms. We focus on four years prior to and five years after the reforms. Post is equal to one

after a country passes the first board reform. The dependent variable is one of the five patent-based measures of innovation, namely, Patent Count, Citation, Cit/Pat, Exploitive Patent and Explorative Patent, all measured as the natural logarithm of one plus the raw measure. Firm controls include Firm Size, Leverage, Profitability and Age. Country controls include GDP per capita, Credit/GDP and Stock/GDP. All Control variables enter the regressions with a one-year lag. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses.

| Dependent Var | Patent Count | Citation | Cit/Pat | Exploitive Patent | Explorative Patent |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| D_4 | -0.0286 | 0.0992 | 0.0865 | 0.0025 | 0.0294 |
| | (0.065) | (0.125) | (0.081) | (0.020) | (0.065) |
| D_3 | -0.0365 | 0.0116 | 0.0106 | 0.0144 | -0.0159 |
| | (0.084) | (0.113) | (0.068) | (0.018) | (0.085) |
| D_2 | -0.0473 | -0.1182 | -0.0958 | -0.0004 | -0.0477 |
| | (0.090) | (0.130) | (0.069) | (0.022) | (0.102) |
| D_1 | -0.1457 | -0.1787 | -0.1164 | -0.0232 | -0.1219 |
| | (0.113) | (0.159) | (0.080) | (0.026) | (0.124) |
| D0 | -0.1982 | -0.2325 | -0.1333 | -0.0464 | -0.1636 |
| | (0.123) | (0.173) | (0.092) | (0.028) | (0.143) |
| D1 | -0.2680* | -0.3597* | -0.2178** | -0.0315 | -0.2278 |
| | (0.135) | (0.187) | (0.093) | (0.032) | (0.161) |
| D2 | -0.3643** | -0.4849** | -0.2760*** | -0.0571 | -0.3336* |
| | (0.153) | (0.202) | (0.097) | (0.034) | (0.183) |
| D3 | -0.4548*** | -0.6010*** | -0.3307*** | -0.0543 | -0.4014** |
| | (0.164) | (0.223) | (0.108) | (0.040) | (0.198) |
| D4 | -0.4377** | -0.5414** | -0.3136** | -0.0591 | -0.3814* |
| | (0.179) | (0.258) | (0.125) | (0.046) | (0.211) |
| Firm Control | Y | Y | Y | Y | Y |
| Country Control | Y | Y | Y | Y | Y |
| Firm FE | Y | Y | Y | Y | Y |
| Industry-Year FE | Y | Y | Y | Y | Y |
| Observations | 90,262 | 90,262 | 90,262 | 90,262 | 90,262 |
| Adjusted R-squared | 0.730 | 0.598 | 0.452 | 0.744 | 0.689 |

Notes: The symbols *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively.

### 4.4 Heterogeneous test

Board reforms often increase short-term performance pressures on management. We hypothesize that mandatory reforms have a stronger negative impact on innovation compared to the “comply-or-explain” approach. As shown

in Table 5 (column 1, 3, 5, and 7), there is a negative correlation between innovation activity and rule-based board reforms.

Table 5 Board Reform Approaches and Corporate Innovation

This table presents the effect of the first board reform on corporate innovation, differentiated by the reform approaches, namely, rule-based and comply-or-explain. Post is equal to one after a country passes the first board reform. The dependent variable is one of the four patent-based measures of innovation, namely, Patent Count, Citation, Cit/Pat, and Explorative Patent, all measured as the natural logarithm of one plus the raw measure. Firm controls include Firm Size, Leverage, Profitability and Age. Country controls include GDP per capita, Credit/GDP and Stock/GDP. All Control variables enter the regressions with a one-year lag. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses.

| Dependent Var | Patent | | Citation | | Cit/Pat | | Explorative Patent | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Rule-based | Comply-or-Explain | Rule-based | Comply-or-Explain | Rule-based | Comply-or-Explain | Rule-based | Comply-or-Explain |
| Post | -0.2700*** | 0.0188 | -0.4158*** | 0.0299 | -0.2280*** | 0.0043 | -0.1755* | 0.0250 |
| | (0.073) | (0.035) | (0.089) | (0.099) | (0.045) | (0.072) | (0.089) | (0.033) |
| Firm Control | Y | Y | Y | Y | Y | Y | Y | Y |
| Country Control | Y | Y | Y | Y | Y | Y | Y | Y |
| Firm FE | Y | Y | Y | Y | Y | Y | Y | Y |
| Industry-Year FE | Y | Y | Y | Y | Y | Y | Y | Y |
| Observations | 66,368 | 23,894 | 66,368 | 23,894 | 66,368 | 23,894 | 66,368 | 23,894 |
| Adjusted R-squared | 0.713 | 0.789 | 0.577 | 0.672 | 0.421 | 0.537 | 0.674 | 0.772 |
| p-value on difference | 0.000 | | 0.001 | | 0.007 | | 0.035 | |

Notes: The symbols *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. The last row is the SUR-estimated p-value for the difference in firm innovation between the two groups.

In highly competitive industries, where profit margins are squeezed, executives are more likely to adopt short-sighted behavior (Raith, 2003). Managers in these environments tend to become more risk-averse (Scharfstein, 1988). Consistent with this, the results in Table 6 show that the negative impact of board reforms on innovation is more pronounced in highly competitive industries.

Table 6 Board Reform and Corporate Innovation: Differentiated by Market Competition

This table presents the heterogenous results of the major board reforms on corporate innovation based on varying degrees of market competition. We measure country-industry specific competition based on the HHI of sales. Post is equal to one after a country passes the first board reform. The dependent variable is one of the four patent-based measures of innovation, namely, Patent Count, Citation, Cit/Pat, and Explorative Patent, all

measured as the natural logarithm of one plus the raw measure. Firm controls include Firm Size, Leverage, Profitability and Age. Country controls include GDP per capita, Credit/GDP and Stock/GDP. All Control variables enter the regressions with a one-year lag. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses.

| **Dependent Var** | **Patent** | | **Citation** | | **Cit/Pat** | | **Explorative Patent** | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | High | Low | High | Low | High | Low | High | Low |
| Post | -0.2065*** | -0.0927** | -0.2895*** | -0.1435* | -0.1499*** | -0.0879* | -0.2692*** | -0.0391 |
| | (0.055) | (0.039) | (0.077) | (0.075) | (0.044) | (0.049) | (0.077) | (0.059) |
| Firm Control | Y | Y | Y | Y | Y | Y | Y | Y |
| Country Control | Y | Y | Y | Y | Y | Y | Y | Y |
| Firm FE | Y | Y | Y | Y | Y | Y | Y | Y |
| Industry-Year FE | Y | Y | Y | Y | Y | Y | Y | Y |
| Observations | 46,874 | 43,001 | 46,874 | 43,001 | 46,874 | 43,001 | 46,874 | 43,001 |
| Adjusted R-squared | 0.681 | 0.779 | 0.564 | 0.626 | 0.414 | 0.485 | 0.636 | 0.743 |
| p-value on difference | (0.02)** | | (0.07)* | | (0.19) | | (0.01)*** | |

Notes: The symbols *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. The last row is the SUR-estimated p-value for the difference in firm innovation between the two groups.

Excessive pressure from board reforms may lead management to prioritize short-term performance over long-term innovation, particularly in firms with high operational uncertainty. Table 7 supports this hypothesis, as all coefficients for patent-based measures in the high-uncertainty group are significantly negative. Moreover, the negative effect is more substantial in the high-uncertainty group compared to the low-uncertainty group.

Table 7 Board Reform and Corporate Innovation: Differentiated by Operational Uncertainty

This table presents the heterogeneous effect of the first board reform on corporate innovation based on the extent of operational uncertainty facing each firm. We measure operational uncertainty using average sales volatility of a firm. Post is the key explanatory variable, which is equal to one after a country passes the first board reform, and zero otherwise. The dependent variable is one of the four patent-based measures of innovation, namely, Patent Count, Citation, Cit/Pat, and Explorative Patent, all measured as the natural logarithm of one plus the raw measure. Firm controls include Firm Size, Leverage, Profitability and Age. Country controls include GDP per capita, Credit/GDP and Stock/GDP. All Control variables enter the regressions with a one-year lag. We include firm and industry-by-year fixed effects. Robust standard errors clustered at the country level are reported in parentheses.

| Dependent Var | Patent | | Citation | | Cit/Pat | | Explorative Patent | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | High | Low | High | Low | High | Low | High | Low |
| Post | -0.2065*** | -0.0927** | -0.2895*** | -0.1435* | -0.1499*** | -0.0879* | -0.2692*** | -0.0391 |
| | (0.055) | (0.039) | (0.077) | (0.075) | (0.044) | (0.049) | (0.077) | (0.059) |
| Firm Control | Y | Y | Y | Y | Y | Y | Y | Y |
| Country Control | Y | Y | Y | Y | Y | Y | Y | Y |
| Firm FE | Y | Y | Y | Y | Y | Y | Y | Y |
| Industry-Year FE | Y | Y | Y | Y | Y | Y | Y | Y |
| Observations | 46,874 | 43,001 | 46,874 | 43,001 | 46,874 | 43,001 | 46,874 | 43,001 |
| Adjusted R-squared | 0.681 | 0.779 | 0.564 | 0.626 | 0.414 | 0.485 | 0.636 | 0.743 |
| p-value on difference | (0.02)** | | (0.07)* | | (0.19) | | (0.01)*** | |

Notes: The t-statistics are provided in parentheses. The symbols *, **, and *** denote significance levels of 10%, 5%, and 1%, respectively. The last row is the SUR-estimated p-value for the difference in firm innovation between the two groups.

## 5 Conclusion

This paper examines the impact of board reforms on innovation outcomes using firm-level data from 58 countries between 2000 and 2015. The results show that board reforms significantly reduce both the quantity and quality of corporate innovation. Specifically, the reforms lead firms to focus more on exploitative innovation rather than explorative innovation. This suggests that stricter board governance fosters managerial short-sightedness, which undermines long-term, high-risk innovation.

This paper makes two key contributions. First, it enhances the literature on corporate innovation by providing a global perspective on the effects of governance mechanisms, addressing inconsistencies in previous studies based on single-country data (mainly from the U.S.). Our findings highlight that stronger board governance negatively affects innovation. Second, this paper contributes to the policy debate on board reforms, illustrating that rigid, one-size-fits-all reforms, as noted by Fauver et al. (2017), are less effective than flexible governance structure in fostering innovation.

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# 數字技術對公司法的挑戰及其系統性回應

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**摘要：**數字經濟時代，人工智能、深度學習模型、互聯網、大數據、雲計算、演算法、區塊鏈等數字技術迅猛發展，並深度嵌入到公司治理當中去。數字技術在提高公司治理效率的同時，也對建立在工業時代基礎上的傳統公司法理論框架與規則體系構成了嚴峻挑戰。其挑戰不僅限於公司內部管理，更觸及到了公司法律形態、股權交易和安全責任等根本制度。我國 2023 年修訂的《公司法》雖然在電子化表決、股東查閱權等方面作出了初步回應，但對數字技術所帶來的的深層挑戰仍顯不足。本文旨在梳理數字技術對公司法在公司形態邊界、數位化新形態、資本結構組成與公司治理模式這四大層面所帶來的核心挑戰，並提出需要構建一個融貫立法、司法、行政監管、公司內部治理及法律解釋的系統性治理格局和協同性法律體系，在鼓勵技術創新的同時，捍衛公司法的公平、問責、秩序與效率價值。

**關鍵詞：**數字技術；公司法；公司形態；公司治理；系統性回應

## 一、問題的提出

公司法領域，數字技術正深度介入公司設立、治理及運營。大數據、區塊鏈等數字技術讓公司內部資訊流動與共享更高效。從初創公司到跨國集團，公司的運轉模式、管理手段、資本結構乃至組織形態都被重塑著。去中心化自治組織（DAO）、人工智能一人公司（OPC）等新型公司形態在數位化催生下不斷湧現。建立在工業時代的傳統公司法律制度，在數字經濟時代開始顯得有些力不從心。《公司法》為公司組織設立、運營管理、融資等設定了一套成熟周密的規則制度。這套傳統的規則預設了公司要有實體辦公地、清晰的管理層級、必要的組織機構、紙質公司章程及股東名冊等。但如今，公司的核心資產可能是一套演算法或是海量數據，重大戰略決策或可由人工智能輔助分析並生成，公司業務或可交由“數字員工”操縱完成。這些新變化使傳統規則面臨看不懂或管不著的尷尬境地。

隨之而來的新問題、新挑戰由此湧現。數字技術的介入，未來公司日益成為一個由代碼、數據和演算法驅動的“數字實體”，我們需要思考現行公司法還能否有效規範與規制。例如，當一家完全靠區塊鏈智能合約運行、沒有傳統管理層的“去中心化自治組織”造成相關利益主體損失時，要如何承擔責任，由誰來擔責。又如當下討論火熱的人工智能 OPC 模式，一位創業者僅憑自己和人工智能系統就能運營一家公司，現行公司法框架下要如何對其運行與治理進行規制。又當董事應用無法解釋其內部邏輯的“黑箱”演算法做出錯誤決策時，法律應如何判斷其對信義義務的履行。

可見，數字技術已從效率工具轉變為法律秩序緊張的根源，直接拷問公司法基本規範的適應性，觸及公司形態、組織架構、資本形態、治理責任等根本問題。儘管 2023 年修訂的《公司法》已經看到數位化浪潮，並作出了積極回應，比如允許電子線上開會、擴大股東電子查閱權等，但這些調整尚未能系統回應上述更深層的制度性難題與挑戰。

本文聚焦數字技術對公司法在公司形態邊界、數位化新形態、資本結構組成與公司治理模式這四大方面帶來的核心挑戰，擯棄單一“立法中心主義”，探索由司法實踐、行政監管、

公司內治與法律解釋共同構成的系統性回應方案，以期在鼓勵公司創新的同時，又能捍衛公平、誠信、責任、秩序的公司法價值。

## 二、數字技術對公司法的核心挑戰

數字技術對公司法的衝擊並非單一維度，而是從組織形態、資本制度與治理機制這三大層面形成了系統性挑戰。這三個層面並非彼此孤立，而是相互嵌套、層層遞進。組織形態的變革是根本性的結構變動，當公司的法律邊界發生位移時，建立在此之上的資本制度和治理機制必然隨之震盪。

### （一）去中心化自治組織使公司的組織形態邊界模糊

區塊鏈技術催生了如“去中心化自治組織”（Decentralized Autonomous Organization，以下簡稱“DAO”）等新型商業組織形式。DAO 設立之初就完全生長在數字世界，它的核心資產、成員關係、運營規則均以數位化的代碼為載體，由嵌入區塊鏈的智能合約自動執行，其就像完全由代碼運行的線上公司。與傳統公司依賴層級化的管理機構不同，DAO 無傳統的中心化管理層，沒有固定的實體總部和中心領導，成員呈現全球化分佈和匿名化，決策權分散於全體各成員手中，依靠智能合約代碼自治運行，完全依賴預設的演算法規則自動完成。DAO 借助代幣實現人機共治，[1] 因 DAO 的股權無限趨近產權而不可契約化，需要在產權、組織與合同三重邏輯下對其內部契約自由進行差異化限制。[2]

傳統公司法以章程、機構為核心，預設了明確的法人實體、註冊地址、法定代表人及層級化的治理結構。然而，DAO 的數位化、去中心化、分散式和自治化特徵，與上述預設產生了根本錯位，使其在法律人格認定、組織設立與登記程式、破產清算等多方面與現行公司法格格不入，或導致 DAO 形態下公司主體資格困境、登記規則失靈、責任追究無門等問題。具體而言，DAO 所面臨的困境主要體現在三個層面。主體資格上，DAO 法人認定存在法律空白。現行法預設法人具可識別的意思機關和獨立的責任財產，而 DAO 分佈式決策機制使其法人意志的形成路徑完全異於傳統邏輯，難以適用現行法人制度。DAO 主體性上與現實法律難以通約。[3] 有學者主張 DAO 應定性為民事合夥，但因缺乏主體資格和有限責任保護，未來應賦予其法人資格。[4] 註冊登記方面，DAO 全球分佈式運營模式與傳統屬地管轄的登記管理方式存在結構性衝突。一家在區塊鏈上運行、成員遍佈全球的組織，應向哪個司法管轄區登記，目前仍缺乏清晰的規則指引。關於信義義務，傳統的公司法以董事會為核心構建了受託人的責任體系，然而 DAO 並沒有傳統意義上的中心管理層，因此難以直接適用既有的責任體系去確定 DAO 信義義務的承擔主體。對此有學者主張對 DAO 的實控成員需從權責匹配角度重構信義體系。[5] 對於上述問題，有學者認為 DAO 法律治理應以‘控制路徑識別——責任歸屬機制’為核心構建邏輯。[6] 亦有學者反思指出，DAO 本身就存在“再中心化”問題，公司法只需適應性改革即可促成和諧共處。[7]

實踐中，這些問題已逐漸顯現。在 2023 年美國 DAO 第一案（CFTC vs. Ooki DAO）中，[8] 法院基本支持了 CFTC 的全部訴訟請求，認定 DAO 需承擔 64 萬美元的罰款並且被永久性關停。該案件明確了 DAO 責任問題上的重要立場，即使 DAO 是去中心化的，且沒有傳統公司的結構，但是其參與者仍然可能面臨法律責任，其仍要遵守現行法規，DAO 並非法外之地。美國懷俄明州已於 2021 年率先通過《DAO 法案》正式承認 DAO 可作為獨立法人實體註冊為 LLC，並通過註冊代理人實現異地運營。[9] 這標誌著 DAO 的法律地位問題已經從理論討論進入了立法實踐。有學者亦指出美國某些州對 DAO 法人地位的承認預示著董事會制度與 AI 技術的融合並非不可能。[10] 對於 DAO 所呈現的問題，DAO 治理應走公法私法協調、硬法軟法共治的道路。[11] 這為 DAO 的規制提供了重要的法律應對思路。

**（二）一人公司的數位化新形態人工智能 OPC 及其挑戰**

數字技術不僅催生了 DAO 等新形態組織，更深刻重塑傳統公司內在運行邏輯。近期湧現出“人工智能 OPC”（One Person Company：一人人工智能公司）模式，這正是數字技術重塑公司組織形態的集中體現。2025 年江蘇首提 OPC 新範式後，多地出臺扶持政策，全國範圍內形成創業熱潮。“人工智能 OPC”是個全新概念，從形式上看，其法律外殼依然是經典的一人有限責任公司。創業者通過工商登記註冊，同樣可獲得法人資格和有限責任保護。其真正特殊之處在於其運營內核，個人創業者借助人工智能獨立完成從產品創意、研發迭代到市場運營、客户服務等全鏈條工作，實現超輕量化運營。有實務人士將這種模式概括為“極簡主義的治理結構 + 高度個體集權 +AI 驅動的管理”。[12] 這種模式凸顯了數字時代下公司的法律人格與治理能力正發生實質性分離。傳統公司法預設需有相應組織機構，協同形成並執行法人意志。人工智能 OPC 模式中，大量決策和執行職能由創業者與 AI 協同完成，並高度依賴 AI 系統。當 AI 深度參與甚至主導公司決策時，應如何認定公司意志的形成，這是否會動搖以自然人決策為基礎的基本治理邏輯。針對人工智能 OPC 單人遠程運營與傳統商事制度存在適配性摩擦，需制度上適應性調整。[13] 與此同時，該模式也對信義義務的履行標準提出了新的複雜性。作為一人公司的股東兼董事，其勤勉義務的履行標準在 AI 深度介入下麵臨新的判斷問題。當決策者嚴重依賴 AI 建議時，如何判斷其盡到“合理注意”，僅要求其理解 AI 系統的底層演算法邏輯，抑或是僅需合理信賴 AI 的輸出，其認定標準存在實際困難，這亦為第 180 條“勤勉義務”認定增添了前所未有的技術難度。當前人工智能仍為輔助決策工具，不具法律主體資格，其行為責任最終歸創業者本人。

此外，人工智能 OPC 模式可能會加劇對法人人格否認的風險。一人公司本就存在股東與公司人格混同的固有風險，《公司法》第 23 條設置了舉證責任倒置的特殊規則，股東若無法證明公司財產獨立於自身財產，則需要對公司債務承擔連帶責任。人工智能 OPC 模式下，公司的核心資產，如數據、演算法模型、公司的運營記錄、與 AI 的交互日誌等數字資產，與股東的運營行為間的界限愈加模糊，更難以清晰區分，也使財產獨立性更難證明，從而在司法實踐中可能更容易觸發“刺破公司面紗”的審查。有學者指出，一人公司由股東過度控制為常態，是其人格混同風險的法理根源。[14] 因此，人工智能 OPC 模式並非簡單的技術應用，它體現數字技術正從內部解構著傳統公司的治理模式，迫使法律要重新審視公司在數字經濟時代的具體內涵，它更像是由人和技術共同驅動、法律外殼與技術內核相結合的新型組織實體。

**（三）資產數位化對公司法傳統資本制度的衝擊**

數字技術深度發展亦深刻改變著公司的資產形態和融資方式。數字經濟時代，公司核心資產已不再局限於廠房、設備和貨幣，數據資訊、用户資源、演算法模型等數位化資產的重要價值日益凸顯。與此同時，區塊鏈及通證技術興起，使數據、知識產權等得以數位化，並催生了 STO（證券型通證發行）這一新型融資方式，它將傳統的金融資產轉化為數字代幣，並在合規監管框架下進行公開發行和交易，再通過區塊鏈技術簡化流程，實現了全天候交易，兼具合規性和效率性。此外，在數字技術使公司的股權登記、轉讓和管理更高效、靈活的同時，其對以實物、貨幣為核心的傳統資本制度構成衝擊，集中體現在出資形式和股權管理兩個維度。

在出資形式層面，數據、演算法等的數字資產能否作為合法有效的出資形式，以及如何對其進行價值評估，這些都將直接觸及《公司法》第 48 條關於非貨幣財產出資的規定，回顧立法演變，股東出資的式經歷了從嚴格到寬鬆的歷程，2023 年進一步擴大範圍，明確增加股權、

債權作為出資形式。趨勢表明，我國公司法對非貨幣性出資的包容性逐步增強，與數據資產出資入股的市場需求相契合。有學者指出，數據資產具經濟價值且符合法定要件的，可作為合法有效的出資形式，[15] 企業數據出資亦順應數字時代公司法的發展趨勢。[16] 然而，數據資產相較傳統非貨幣財產，具無形性、價值易變性、權屬認定複雜等獨特屬性，將其納入出資範疇，還需在資產評估、權屬確認、風險控制等方面建立更細緻的規則體系。

在股權管理方面，區塊鏈技術為股東名冊及股權工商登記的整合提供了契機。[17] 然而，基於區塊鏈的股權代幣化引發了更複雜的法律問題。其將公司股份轉換為在區塊鏈上發行的數字代幣，這一技術使股權管理可超越傳統工商登記系統，實現在鏈上即時確權與流轉。但隨之而來的問題是關於區塊鏈上登記的股東名冊的法律效力問題，其是否具有與工商登記同等法律效力，當鏈上確權與工商登記不一致時應以何者為准。此外，股權代幣化還帶來了股權“一鍵轉讓”、全天候全球快速股權交易等的新特徵，這些新變化與現行公司法中關於股東優先購買權、股權登記等規則如何協調，同樣是亟待回答的問題。

**（四）數據與演算法驅動使公司治理與責任認定的複雜化**

在公司內部治理層面，數字技術的深度介入使得傳統的權力配置、信義義務履行及風險規制邏輯趨於複雜。

演算法決策“黑箱”特性模糊了董事勤勉義務的司法認定標準。AI 輔助決策使經營決策過程變得不透明、難以解釋。當基於演算法輔助作出的決策使公司受損，法官難以依據“合理注意”標準來判斷董事是否盡到勤勉義務，這問題直接衝擊了《公司法》第 180 條的適用。傳統上，主要依賴對決策流程和資訊獲取過程的司法審查，但演算法決策“黑箱”使過程審查一定程度上失效，導致歸責的困難。目前，人工智能介入主要是輔助決策，人類決策權仍是主導，但決策的整體環境已顯著變化，義務逃避與責任模糊問題凸顯，傳統信義義務內容與責任監督機制無法準確回應智能衝擊，需加以重構。[18] 這揭示了問題的深層邏輯，數字技術所帶來的挑戰並非是要替代人類決策，而是要在人機協作的新模式下要重新定義“合理注意”的內涵。

數字技術賦能股東的新趨勢正在衝擊著公司法既定的權力配置結構。區塊鏈、大數據、互聯網、電子平臺、線上會議等技術廣泛應用，極大降低了股東（尤其是中小股東）參與決策、實施監督的成本，使公司治理趨向“去中心化”“管理層級扁平化”“股東積極主義”，該趨勢在實踐中可能弱化董事會作為公司決策核心的法定地位。現行公司法設置的“股東會—董事會—監事會”權力制衡結構或面臨被架空的風險。對此，有學者指出，當前核心問題已從代理成本轉向社會如何向權力集中的科技公司控制者問責，[19] 公司治理研究應從重視掌握核心技術和關鍵資源的創始團隊，[20] 並可以遵循“數據賦能 - 技術驅動 - 治理變革”的治理邏輯展開。[21] 當前《公司法》第 24 條等電子化條款僅解決了參與形式的問題，但並未回應權力實質從董事會向股東乃至外部技術平臺轉移，所帶來的決策效率、權威性以及最終責任承擔主體等諸多法律問題。

公司治理數位化還衍生出了新型的技術代理成本與企業合規風險。實證研究表明，數字技術創新賦能公司治理顯著提升了企業治理水準。[22] 然而，數字技術在提升數據透明度、公開度的同時，也隨之帶來數據洩露、演算法歧視、資訊超載等負面效應，以及產生為維護技術系統而產生的額外的新型代理成本及代理風險。管理者可能利用技術壁壘、演算法歧視、數據壟斷等來實施“數字式”機會主義，也即以看似技術中立的方式，通過複雜演算法或數據優勢為自己謀取不當利益，而監督者或因技術能力限制難以有效識別和制止。現行公司法主要規制財務與忠誠風險，對數據安全責任、

演算法公平性審查、技術系統風險管理等新型數位化問題的規制仍存空白。[23] 董事信義義務範疇是否應拓展至“技術合規”與“數據倫理”，已成為有待明確的法律問題。

綜上，數字技術對公司法的挑戰呈現出多層次、系統性特徵。從 DAO 對組織形態邊界的模糊，到人工智能 OPC 對傳統治理邏輯的解構，再到公司資產數位化對資本制度的衝擊，及數據與演算法對公司治理與責任認定的複雜化，這四個層面的挑戰相互交織，共同構成數字經濟時代公司法必須直面的核心問題。這些挑戰的根本共同點在於，傳統公司法以工業時代的物理實體、紙質憑證和自然人決策為基礎所構建的規則體系，在面對代碼、數據和演算法等主導的數位化商業實踐時，其解釋力與適用性正受到系統性考驗。理解這些挑戰的結構與機理，是構建有效應對方案的前提。

## 三、《公司法》對數字技術的初步回應及其系統性不足

面對數字技術對傳統公司法規則的系統性衝擊，2023 年修訂的《公司法》在確認電子通信方式（第 24 條）、擴大股東查閱權範圍、審計委員會的設立、信義義務內涵的明確（第 180 條）等方面作出了初步的回應，為非貨幣財產出資提供了開放性框架（第 48 條）。這些回應體現了立法者對數字化趨勢釋放出的積極制度信號，為公司數字運營治理提供了初步法律介面。然而，這些回應更多是點狀式回應和工具性調整，針對前述公司在組織形態、資本制度與治理機制上所面臨的三重挑戰，現行法存在諸多立法空白。置於現行法體系框架之下，應對公司的數字挑戰，在司法裁判指引、監管標準細化、內部治理引導等方面均存在不足，公司法缺乏系統性的回應。面對具體的數字糾紛時，仍主要依賴法官自由裁量與公司的自行探索，缺乏穩定預期。

### （一）公司法順應數位化的初步回應不足

現行法在電子化上的積極回應，其進步意義應予肯定，但是當前其回應方式存在明顯點狀性與工具性，主要是在既有法律框架內對傳統規則進行數位化適配，而未能體系化地回應前文所述數字技術介入公司帶來的深層結構性挑戰。

電子通信會議制度是其中最為突出的例證。現行法第 24 條承認了電子通信方式召開會議和表決的效力，但在召集通知、議事程式、表決規則及會議記錄上都缺乏細化規定，身份確認、資訊傳遞等技術瑕疵易引發效力爭議。[24] 但書條款賦予公司章程排除適用該制度的自治權，但該設置在實踐中存在被控股股東濫用的風險，或通過設置現場參會強制要求、縮短通知期限等方式實質排除中小股東的參會權，導致效率與公平間的價值衝突。這表明，現行法在電子化會議的程式保障和中小股東利益保護方面，仍存在不足之處。

關於數據資產與資本制度，第 48 條雖為非貨幣財產出資提供了“可用貨幣估價並可依法轉讓”的開放性標準，但對數據資產出資的具體制度供給嚴重不足。數據財產出資面臨登記制度缺失、價值評估機制模糊、出資瑕疵責任約束薄弱等困境。[25] 此外，基於區塊鏈股權代幣化等新型股權管理方式所引發的法律問題，諸如鏈上確權與工商登記間的效力衝突、全球快速交易、股東優先購買權協調等數字技術帶來的新挑戰，現行法對此尚未涉及。針對數字時代所湧現的公司新型組織形態與數字治理模式，現行法的回應缺位更明顯。DAO 法律主體地位問題、人工智能 OPC 模式在法律人格與治理能力分離下對傳統公司的治理邏輯、結構的衝擊，及演算法決策“黑箱”對董事勤勉義務認定標準的複雜化等諸多智能化產生的新問題，亦尚待法律作出全面系統的回應。

### （二）公司法應對數字技術挑戰的系統性缺失

現行公司法對數字化挑戰的回應局限不只在具體制度供給的不足，更重要的是其未能結合司法裁判、行政監管、內部治理等多方面構

建起多層次、協同性的系統性回應體系。畢竟法律的滯後性無可避免，立法完善需要漫長的週期，眼前不在於死抓立法空白不放，當前更可行也更有效的解決方案在於，在現行的法治運行體系框架內，調動多方力量，實現公司法對數字挑戰的適用性發展。目前，應對數字技術挑戰，現行公司法在司法裁判指引、行政監管標準供給和公司內部治理引導等多方面，仍存在顯著的系統性缺位。

在司法審理層面，面對演算法侵權、數據濫用、DAO 法律地位認定、人工智能 OPC 人格混同認定等新型糾紛，法官缺乏可資參照的統一裁判標準和指導性案例。現行法對數字技術相關問題的回應多為原則性的規定，在具體爭議的裁量尺度上存在較大不確定性，導致法律適用高度依賴法官自由裁量，難以形成穩定的裁判預期。在行政監管層面，針對數據資產出資、股權代幣化管理、演算法決策透明度要求等具體事項, 尚未出臺具操作性的配套指引。關於公司內部治理，現行法雖通過審計委員會制度強化了董事的監督職能，但缺乏對公司章程自治中涉及數字治理事項的系統性指引。 三方面的協同缺位，使現行公司法面對數字技術挑戰時系統性回應缺失的實質不足。

綜上，現行公司法在數位化回應方面的積極嘗試應予肯定，但其回應呈現出顯著點狀性和工具性特徵，尚未能有效回應數字技術帶來的核心挑戰。制度現狀表明，面對數字技術從組織形態、資本制度到治理模式對公司法的全方位衝擊，單純的立法修訂已不足以應對。基於立法工作的嚴謹性，對新興領域的規制不宜隨意開道。因此，需要在其他環節積極適應數位化變革，從司法實踐、行政監管與公司內部治理等多個層面，構建一套多層次、協同性、系統性的回應方案。

## 四、公司法應對數字技術挑戰的系統性回應路徑

面對數字技術對公司法提出的多重挑戰，固守單一的立法修訂模式已不足以有效回應。現行公司法的點狀回應難以體系化解決 DAO 法律地位懸置、人工智能 OPC 模式的治理結構問題、數據資產出資制度供給不足、演算法決策歸責困難等的諸多難題。問題根源在於，立法活動週期長、程式嚴的特點，難以對日新月異的技術變革作出及時回饋。因此，應對數字挑戰的關鍵在於超越對“立法中心主義”的依賴，轉而構建一個多層次、協同性、系統性的回應方案，在司法裁判、行政登記、行政監管、公司內部治理與法律解釋等多維度協同發力，形成合力。

### （一）以指導性案例細化數字時代的司法標準與責任邊界

司法裁判是法律回應社會變革的基礎性路徑。面對新型數字技術引發的糾紛，最高人民法院可通過發佈典型案例或指導案例，逐步確立數字環境下糾紛的審查要素和裁判標準。

在演算法決策的歸責問題上，可以明確規定董事在採用演算法輔助決策時應負有“技術盡職調查”的義務, 瞭解其基本原理、數據來源、潛在偏見等。決策過程中，保留必要的人工干預節點，確保在關鍵環節人類判斷和決策的介入，而非將決策權完全讓渡給演算法。對技術決策的潛在風險，還需建立持續監督機制，定期評估演算法系統的運行狀況及其對公司和利益相關者的影響。通過案例的逐步積累，相信可以使“通常應有的合理注意”這一抽象標準，在數字語境中可獲得具體化、可操作的判斷依據，在不修改條文的前提下實現裁判規則的與時俱進。這一思路對於數字時代的公司實際控制者的責任認定同樣具重要的參照意義。

在人工智能 OPC 模式的法人人格否認問題上，當一人公司面臨法人人格否認訴訟時，法院應審慎審查股東財產與公司財產的獨立性，同時充分考慮人工智能工具這一特殊要素。有學者強調，財產混同的認定須經嚴格的審判程式，不宜在執行程式直接追加股東。[26] 此外，關於 AI 系統的交互記錄是否構成公司的運營痕跡、演算法模型是否應當被認定為公司核心資

產、技術行為與公司行為間的邊界如何劃定，這些問題的裁判標準待需在個案中逐步形成。因此，法院在審理此類案件時，既不能因技術新穎性而放鬆對人格混同的審查標準，也不能因一人公司的特殊性而輕易否認其法人人格。通過指導案例明確人格混同的認定要素和舉證責任的分配規則，為人工智能 OPC 模式運行提供穩定的法律預期具重要現實意義，同時也可一定程度避免有限責任制度被不當突破。

**（二）創新適用行政登記為新型組織與資本形態提供入口**

行政登記制度是連接法律規範與商業實踐的重要橋樑，為公司新型組織形態和資本形式提供制度入口，是回應數字挑戰的關鍵環節。尤其是 DAO 這一新型的組織形態有望成為傳統公司治理提供制度創新靈感。[27] 面對 DAO 在法律人格認定上的困境，可以考慮授權地方或特定區域開展試點，為 DAO 等新型組織提供臨時性法律身份，探索其主體登記、運行監管、責任規制等的新模式。DAO 具有不同於公司的特性，對其治理不能簡單地參照適用合夥企業法或公司法，需要探索出獨特的治理路徑。通過試點積累監管經驗，在條件成熟時再推向全國的制度設計，是一種務實可行的漸進式適應路徑。

在數據資產出資方面，《公司登記管理實施辦法》第六條已邁出重要一步，明確規定“法律對數據權屬等有規定的，股東可按規定用數據作價出資”，這為數據資產出資的合法性提供了初步的登記依據。然而，數據資產相較於傳統形式，具價值易變性、權屬認定複雜、可複製性強等獨特屬性，未來的制度建設需著力解決數據資產的動態估值標準、法律權屬認定、權利瑕疵、重複出資風險等問題。在數據資產出資瑕疵的情況下，出資股東的責任承擔方式、其他股東的補充出資義務以及公司債權人的救濟路徑等問題，同樣需要明確的規則指引。因此，可以由相關部門制定專門的公司數據資產登記與出資指引，這將有助於為數字化實踐提供明確的合規預期，將創新納入有序的監管視野。

在股權管理方面，股權代幣化帶來的區塊鏈上確權與工商登記間的效力衝突，同樣需要登記制度的適應性調整。區塊鏈分佈式帳本技術為股權登記提供了新的技術方案，部分法域（如瑞士）已經允許區塊鏈本身作為法定股份登記冊，這一經驗可供借鑒。未來可探索建立鏈上登記與工商登記的效力銜接機制，明確效力衝突時的選擇標準，同時保障股東優先購買權等法定權利在數字環境下有效實現。可以通過制定公司區塊鏈股權管理指引等，為數字化環境下的股權管理實踐提供明確具體的規範路徑。

**（三）完善技術治理與資訊披露等補充性行政監管規則**

行政監管在公司數字技術治理的重要規則補充和行為引導。相關機構可出臺專門的公司數字技術治理指引等，要求其披露關鍵演算法的基本原理與潛在偏見，建立數據安全管控體系，將技術風險管理納入公司年報的治理結構部分來說明等。這類監管指引能為司法裁判提供事實依據，為股東監督提供資訊披露支撐。同時，可以在不增加立法成本的前提下，實現對數字技術應用的行為規範。中國證監會科技監管司的認可了這一趨向，其強調“加強資訊披露和投資者保護，保障投資者知情權與選擇權。”這些重要的監管思路為數字技術在公司運營治理中的應用劃定了行為底線。

在人工智能 OPC 模式下，監管規則需要特別關注 AI 工具使用的透明度要求。由於一人公司缺乏內部機構制衡機制，創業者使用 AI 系統進行決策的過程以及依據往往不為外部所知，這為數字式機會主義行為的滋生留下了空間。因此，應要求人工智能 OPC 在年度報告中披露其使用 AI 工具的範圍、程度及對公司運營的影響，以便於監管機構和利益相關者評估其治理品質和風險水準。同時，應當關注一人公司財產獨立性的制度保障，通過要求其建立規範的財務管理制度以及獨立的會計核算體系，從源頭防範人格混同風險。

**（四）引導公司內部章程將合規要求轉化為治理實踐**

公司內部治理是法律規制的重要延伸和關鍵補充。數字時代，引導公司通過章程自治和機構設置將合規要求轉化為治理實踐，是回應數位化挑戰的重要舉措。內部機構設置上，可以鼓勵與引導公司在董事會下設置“科技倫理委員會”或者“數據治理委員會”，負責對重大演算法模型、數據應用專案等進行操作的合規性審查及技術倫理性審查。這一內部機構的設置與運作，應被視為董事履行其勤勉義務、積極應對數字風險的重要表現，並可作為重要的裁判認定依據。通過設置專門委員會，可以在公司的內部建立對數字技術應用的常態化監督機制。

公司章程方面，可以鼓勵公司在內部治理的框架內，通過自主設定數據資產權屬、數據使用規則以及通證化股權的轉讓限制等，發揮公司章程在數字治理上的靈活性和高效性。例如，對於數據適用規則，在明確數據歸屬的基礎上，劃定數據使用的邊界條件；對於股權代幣化，規定鏈上股權轉讓的程式和條件，以及明確股東優先購買權在數字環境下的行使方式。對於人工智能 OPC 這類高度依賴技術工具的公司形態，雖無需設立複雜的組織結構，但仍應通過章程來明確 AI 決策與人工決策間的權責邊界，建立規範的財務管理制度以防範人格混同風險。對此亦有學者主張，可針對單人運營特徵出臺標準化財務規範指引與操作範本，[28] 未來監管要加強對科技公司的關注及其數據治理。[29] 這些觀點為引導公司內部治理的數位化轉型提供了重要的理論參照。

**（五）運用法教義學填充規則空白拓展法律解釋空間**

在立法滯後的過渡期內，運用法教義學方法填充規則空白，是應對數字挑戰的務實路徑。法律解釋的優勢在於其靈活性和即時性，它能在不需要修改條文的前提下，通過對現有規範的釋法說理，將新事物納入既有的法律框架之中。

信義義務方面，可以將“演算法公平”“數據安全”等公司數位化治理要求，通過擴大解釋納入第 180 條“忠實義務”與“勤勉義務”範疇。前者的核心在於避免利益衝突，當管理者利用演算法或數據優勢為自己謀取不正當利益時，其行為實質上構成了對忠實義務的違反。後者的核心在於要求董事謹慎、勤勉地履職，當其未經審查就盲目採納演算法輸出，或未盡對技術風險的基本注意義務時，同樣會違反義務。因此，通過將“技術合規”與“數據倫理審查”解釋為勤勉義務的當然延伸，可以在不修改條文的情況下，為數字時代的董事行為提供規範指引。數字時代的公司法需在規範層面積極回應被代理人成本問題，實現權責統一。[30]

在資本制度領域，可以通過法律解釋將符合特定條件的“數據資產”“演算法”納入第 48 條所規定的非貨幣出資的“財產”範疇。現行公司法以強化股東出資義務為導向，為非貨幣財產出資形式提供了“可用貨幣估價並可依法轉讓”這一開放性標準。數據資產雖在物理形態上與傳統財產不同，但只要是符合法定條件的非貨幣財產，就應可用於出資。法律解釋的任務在於，在司法實踐中逐步明確數據資產“可估價”和“可轉讓”的判斷標準，從而為數據資產出資提供法教義學上的依據。公司法的出資形式亦可適當地吸納域外經驗實行概括主義，其優勢在於靈活性，它夠在立法滯後於技術發展的過渡期內，為法律實踐提供相對明確的指引，實現規則的與時俱進。

## 五、結語

數字技術對公司法的挑戰，是一場從形式到實質、從局部到系統的深刻變革，其本質上是是工業時代法律與數字時代現實的脫節。應對這一數位化挑戰，不能僅依賴於一部完美的法律，而必須轉向動態的、多方的系統性治理。數字技術對公司法挑戰的系統性回應路徑，需要司法裁判、行政登記、行政監管、公司內部治理與法律解釋這五個層面協同發力。司法裁判在個案中形成具體規則，為數字時代的公司治理糾紛提供可預期的裁判標準；行政登記為

公司的新型組織形態和資本形式提供制度入口，在試點中積累經驗；行政監管設定行為底線與資訊披露標準，在不增加立法成本的前提下形成規範約束；公司內部治理通過章程自治和專門委員會設置，將外部合規要求轉化為內部治理實踐；法律解釋則在立法滯後的過渡期內彌合規則與現實之間的鴻溝。這五個層面各有側重又相互支撐，共同構成系統性治理格局，使公司法在數字經濟時代持續煥發新的生命力。這一格局並不追求一次性解決所有問題，而是在勇於承認法律滯後於技術發展的客觀現實基礎上，通過多元主體在多個環節協同努力，使得公司法在擁抱數字創新的同時，堅守其公平、秩序與責任的核心制度價值，實現公司法律體系穩健發展與完善。未來，數字技術的迭代不會停歇，公司法與數字技術之間的互動與適應也必將是一個持續演進的過程。本文提出的系統性回應方案，旨在為這一長期的發展進程提供一個可行有效的起點，而非終點。

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# Challenges of Digital Technology to Company Law and Their Systematic Responses

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**Abstract:** In the era of the digital economy, digital technologies such as artificial intelligence, deep learning models, the Internet, big data, cloud computing, algorithms, and blockchain are developing rapidly and becoming deeply embedded in corporate governance. While these technologies enhance the efficiency of corporate governance, they also pose serious challenges to the theoretical framework and rule system of traditional corporate law, which was built on the foundation of the industrial age. These challenges are not limited to internal corporate management but also touch upon fundamental institutions such as corporate legal forms, equity transactions, and security liability. Although China's Company Law, revised in 2023, has made preliminary responses in areas such as electronic voting and shareholders' inspection rights, it remains insufficient to address the profound challenges brought by digital technology. This article aims to identify the core challenges that digital technology poses to company law in four dimensions: the boundaries of corporate forms, new digital forms, the composition of capital structure, and corporate governance models. It further proposes the need to construct a systematic governance framework and a collaborative legal system that integrates legislation, the judiciary, administrative regulation, internal corporate governance, and legal interpretation. Such a system, while encouraging technological innovation, should also safeguard the values of fairness, accountability, order, and efficiency in company law.

**Keywords:** Digital Technology; Company Law; Corporate Form; Corporate Governance; Systematic Response

# 協同與斷裂：廣清一體化營商環境政企話語的實證考察*

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**摘要：**營商環境的優化不僅是制度完善的過程，更是政企話語互通與意義建構的過程。本文以語篇回指為理論框架，自建清遠市營商環境政策文本及廣清產業園企業回饋為研究語料，採用語料庫量化與認知語用分析方法，實證考察廣清一體化背景下政企話語的協同與斷裂機制。研究發現，政企雙方在宏觀目標層面通過辭彙複現回指實現較高度話語協同；但在微觀政策執行層面上，由於代詞回指指稱跨度大、零形回指主體缺位和間接回指語義錯位三個方面導致了明顯的話語斷裂。因此本文提出縮短指稱距離、明確執行主體、構建回指對齊機制三條語篇優化策略，為清遠市進一步優化營商環境提供了語用策略和現實建議。

**關鍵詞：**營商環境；語篇回指；廣清一體化；政企話語；話語協同與斷裂

## 一、引言

優化營商環境是減輕市場主體負擔、助力市場主體發展和培育高端產業的重要舉措[1]。李克強總理（2018）在國務院常務會議上首次指出：優化營商環境就是解放生產力、就是提高綜合競爭力。只有營商環境好，市場主體的活力和創造力才能被充分激發。隨著《廣清一體化“十四五”發展規劃》深入實施，廣清融合已從基礎設施一體化邁向公共服務、營商環境等高階協同階段。打造良好的營商環境，是清遠“入珠融灣”及其承接廣州產業轉移的關鍵抓手。目前學者對於營商環境的研究多數從經濟學和公共管理視角出發，側重分析制度設計與績效評估，較少從應用語言學與話語分析層面揭示政策傳播與政企互動的微觀機制，難以解釋“政策出臺充分、企業感知不足”和“文本表述完善、落地執行不暢”等現實問題。

話語是政企互動的核心媒介，而語篇回指既是語篇銜接手段，也是認知語境中概念實體追蹤與意義解碼的核心機制，能夠精准診斷政策文本與企業回饋之間的認知對接障礙。本文以清遠市營商環境政策文本為供給話語，以廣清產業園企業回饋為需求話語，重點從人稱回指、代詞回指、零形回指和間接回指等四個模式的使用差異展開分析，揭示廣清一體化背景下政企話語在何處協同、緣何斷裂，旨在為區域一體化背景下營商環境優化提供可操作的話語治理方案，同時豐富政務話語分析與語篇回指理論的應用場景。

## 二、文獻綜述與理論框架

### （一）營商環境的內涵

2019 年，中共中央國務院正式發佈《優化營商環境條例》[2]，將營商環境內涵界定為：“企業等市場主體在市場經濟活動中所涉及的體制機制性因素和條件”，由於本文旨在透過清遠市政策文本探究其優化營商環境的政策效果，故在此將根據這一定義，在制度規範的範疇內對營商環境進行研究。

* 基金專案：2025 年度清遠市哲學社會科學規劃課題《廣清一體化背景下營商環境優化的語篇回指策略研究 ——基於清遠市政策文本與企業回饋的實證分析》（課題編號：QYSK2025057）

### （二）營商環境與政企話語互動

日前，政企互信與營商環境的關係越來越受到學者們的關注。現有營商環境研究多從經濟學、公共管理視角展開，聚焦制度設計、績效評價、政策工具與制度性交易成本等議題[3][4][5]。也有研究指出，政策文本可讀性與政企溝通效率直接影響惠企政策落地效果，官方話語與企業訴求話語錯位容易導致政策感知度低，執行受到阻礙[6]。此外，國外學者 Rodrik Dani 等[7]對營商環境的影響因素展開了研究，他們指出政商關係和政務服務效率等因素可以影響營商環境品質。Oded Shenkar&Yadong Luo&Tailan Chi[8] 專門討論了在全球化及新冠肺炎疫情背景下，應更加重視政府角色與產業政策對營商環境的重要性。

總而言之，雖然學界對於營商環境的研究已有了一定的成果，但研究仍存在不足。一是以廣清一體化作為研究對象的相關文獻較少，且目前國內關於營商環境的研究多以國家、發達省份和城市群等宏觀為視角，對廣清一體化這一微觀的地域的研究較少。二是缺少語言學微觀機制分析，也有未引入語篇回指等認知語用工具，這難以揭示話語斷裂的深層成因。

### （三）語篇回指理論及其應用研究

語篇回指是認知語用學與話語分析的核心議題，Halliday & Hasan[9] 將其界定為語篇中回指語的解釋需依賴先行語的語言現象，奠定了回指作為語篇銜接手段的理論基礎。國內外關於回指的研究，一般分為兩種：句內回指和語篇回指研究，其依據是回指所在的語言單位的範圍，形式學派主要研究對象是句內回指，而功能學派基本上集中於語篇回指研究[10][11]。上世紀 80 年代，回指現象受到中國學者們的關注，他們從不同的角度探討語篇回指與句內回指問題。從研究路徑來看，部有的學者從句法結構與指稱形式入手，側重於句內回指分析[12][13][14]。有的從語篇特徵、語篇結構以及語用和認知的角度進行的[15][16][17]。徐赳赳則運用話語分析理論，系統考察現代漢語語篇中的回指現象。劉風光與劉詩宇[18]進一步探索了認知與批評語用相融合的話語分析路徑，為回指理論的跨領域應用提供了新思路。

目前回指理論已廣泛應用於新聞敘事、教育教學、新媒體話語等領域，但在政務服務、營商環境、政企互動等實踐場域的應用明顯不足，尤其缺乏將“回指失效”與政策理解偏差、政企溝通障礙、政策執行梗阻建立直接關聯的實證研究，尚未挖掘出回指機制在政務話語與企業訴求話語對接中的核心作用。

綜上，營商環境研究亟需語言學工具提供微觀解釋，政務話語分析需要認知回指視角深化對溝通機制的拆解，而廣清一體化背景下營商環境的政企話語互動研究仍存在明顯學術空白。同時，現有回指理論的應用場景尚未覆蓋區域一體化營商環境建設，未能發揮其診斷話語銜接障礙的核心價值。本文以語篇回指為核心分析框架，結合語料庫量化與認知語用分析方法，開展清遠市營商環境政策供給話語與企業需求話語的對比實證分析，系統揭示政企話語協同與斷裂的語言學機制，既豐富回指理論在政務治理領域的應用場景，也為清遠市優化營商環境、提升“廣清通辦”效能提供可操作的話語治理策略，兼具理論創新與現實實踐價值。

## 三、研究設計與語料來源

### （一）語料來源

本文採取實證分析方法，自建“清遠市營商環境政企互動微型語料庫”，語料時間範圍為 2021–2025 年，總字數約 5 萬字，詳細情況見下表。

表1：清遠市營商環境政企互動微型語料庫

| 语料类别 | 具体来源 | 字数（约） | 数据获取渠道 |
|---|---|---|---|
| 供给侧（政策文本） | 《广清一体化“十四五”发展规划》第八章“打造融通一体的营商环境” | 20,000 字 | 清远市政府官网 |
| | 《广清产业园优化提升营商环境十大行动方案》 | 3,000 字 | 广清产业园官方微信公众号 |
| | 《营商环境整改材料 11.26》 | 2,000 字 | 广清产业园工作人员 |
| | 《即日起，这些事项我们“帮你办”》 | 1,500 字 | 公开获取 |
| | 《广清茶话荟》相关报道 | 1,000 字 | 公开获取 |
| | 广清产业园“十五五”开局提速重点项目密集落地产业能级加速跃升 | 1,600 字 | 公开获取 |
| | 小计 | 29,100 字 | |
| 需求侧（企业反馈） | “帮办导办专窗”咨询记录 | 5,000 字 | 广清产业园工作人员 |
| | 微信公众号后台企业留言 | 3,000 字 | 线上留言平台 |
| | 企业筹建工作会议纪要 | 8,000 字 | 广清产业园工作人员 |
| | 《促进园区提质增效实施方案 3.0》企业反馈 | 2,000 字 | 书面反馈材料 |
| | 《广清携手兴产业，双向协同惠民生》《泰亚科技》等企业家访谈报道 | 5,000 字 | 公开获取 |
| | 小计 | 23,000 字 | |
| 合计 | 总计 | 约 52,100 字 | 覆盖线上留言、线下咨询、会议座谈、深度访谈四类反馈渠道 |

### （二）研究方法

本文主要採用語料庫量化分析及其認知語用人工標注相結合的方法。一是借助語料庫分析軟體 AntConc 對“該、此、其、這”等代詞回指、零形回指以及“一站式 +、最多跑一次”等核心營商辭彙進行統計分析，對每一條語料逐一排查。二是結合語用學的人工標注，由兩名研究者對檢索結果進行獨立雙人標注，識別代詞回指、零形回指和間接回指與先行語位置及指稱匹配度。三是對比政策文本與企業回饋在回指可及性、指稱對齊度上的差異，揭示政企話語協同與斷裂的語言學機制。

## 四、廣清一體化營商環境政企話語的協同態勢

本文通過語料庫分析法，從辭彙回指和人稱回指兩個維度考察廣清一體化背景下政企話語的協同特徵。

### （一）宏觀目標層面：辭彙複現回指與話語共識

通過 AntConc 對語料庫的檢索統計發現，政策文本中雖未高頻提及營商環境核心關鍵字，但企業回饋對政策文本中出現的關鍵字形成了精准的辭彙複現回指，成為政企在廣清一體化營商環境建設中建構核心共識的重要語言學方式，如例：

（1）政策文本：設置“一窗受理”綜合服務專窗，將可協同、可聯辦行政審批事項和公共服務事項梳理整合成“一件事情”。

（2）企業回饋：現在園區設立了“一窗受理”窗口，辦理不動產登記確實方便。

本例中，當政策文本發佈後，企業會通過“一窗受理”窗口原詞複現精准回指政策概念，體現了對政策理念的認同與接納，這在一定程度上形成了精准的辭彙複現回指。再如：

（3）政策文本：建立幫辦代辦機制，組建專業化幫辦代辦隊伍，提供免費刻章、郵寄服務，為企業提供全流程、全生命週期服務。

（4）企業回饋：現在園區有專門的“幫辦隊伍”，從註冊到投產都有人跟。

在該例中，雖然企業回饋中未完整複現“幫辦代辦機制”，但用“幫辦隊伍”回指政策意圖，準確傳遞了“全生命週期服務”的核心目

標，屬於有效的簡化型同義複現，這也是企業對政策理念認同的表現形式。

通過以上對語料的分析，政策擬定的“一窗受理”和“幫辦代辦機制”等先行語被企業準確接收並原樣回指，說明清遠市政府在對標廣州開發區服務標準和簡化行政審批流程方面的宣傳與實踐，已經成功轉化為企業的認知圖式，正是基於這種辭彙複現的話語協同，大大降低了政企溝通的制度性交易成本。

**（二）身份建構層面：人稱回指與共同體意識**

在廣清產業園推行的“幫辦導辦”服務中，第一人稱複數的高頻使用驗證了政府話語呈現出從傳統客觀化陳述向互動性話語的轉變，如例：

（5）園區黨工委書記褚大軍曾說：“招商要拼真心，我們自己就是最好的榜樣。”

在本例中，園區黨工委書記的說辭裏的這種第一人稱複數的使用，體現了政府從“權威發佈者”向“服務共同體”的角色轉型，他的說辭將政府與企業置於同一解決問題的共同體中，從而進一步強化了這一共格關係。再如：

（6）泰亞科技副總經理柯永傑表示：“來到廣清產業園，幾乎相當於‘來到廣州黃埔’”。

（7）多位企業家評價：“廣清我家”、“來到廣清園，如魚入海”和“在廣清園就像在廣州一樣”。

以上例子同樣出現“咱們園區”和“我們廣清人”等回指方式，這些企業家的表述共同指向一個核心，體現了企業對“我們”這一共格關係認可，即企業已將園區視為“自己人”的共同體，更有甚者，用“來到”也證明把廣清產業園當成一個家，是一種從外到裏的方向行駛。

由此分析，企業認同“我們”，即第一人稱複數回指標志著話語協同的真正達成，政企雙方共同體意識形成，為“清遠成本、廣州服務”品牌形象的塑造提供了話語支撐。

## 五、廣清一體化營商環境政企話語的斷裂表徵

儘管在宏觀理念上高度協同，但在微觀的政策執行與具體訴求對接中，依然存在明顯的話語斷裂。從語篇回指的視角來看，主要表徵為以下三種困境：

**（一）指稱跨度不對稱導致代詞回指失效——企業“看不懂政策”的語言根源**

政策文本為了追求嚴謹與概括，常使用複雜的長句，並輔以“該”、“此”、“其”等指示代詞進行回指。當先行語是一個高度濃縮的複合概念時，指稱跨度過長、內涵抽象，企業難以準確定位其轄域邊界，如例：

（8）園區提出“探索建立公平互惠的稅收分成制度，並推廣至其他合作共建園區。推動該項制度在更大範圍落地見效。”

（9）泰亞科技副總經理柯永傑在訪談中追問：“這個政策具體怎麼落實？它的適用範圍到底包括哪些？”“請問我們清新產業園算不算這個政策裏的‘其他園區’？”

例（8）的先零形回指行語“公平互惠的稅收分成制度，並推廣至其他合作共建園區”是一個高度濃縮的複合概念，而例（9）企業受限於專業背景和資訊不對稱，在使用代詞“這個政策”和“它”進行回指時，由於先行語指稱跨度長、概念抽象，導致企業無法準確定位其適用範圍，容易造成認知斷裂。

分析可得，政府話語的“抽象化”與企業話語的“具象化”需求產生碰撞，造成了認知斷裂，這也是企業反映“找不到政策、看不懂政策”的根源，也是政策文本擬定時需要注意的關鍵。

**（二）零形回指造成的主體缺位——企業“找不到門路”的語篇癥結**

零形回指實際上是一種省略現象，是一種通達性極高和保持語篇連貫的回指手段（徐赳赳，2003），在清遠的政策文本中，這種現象

尤為普遍，如例：

（10）政策文本：（Ø）清理和規範廣清兩地不合規補貼，（Ø）廢除有名無實的“支持政策”。(用符號Ø表示零形回指的主語位置)。

（11）企業回饋：之前申請的互聯網跨市補貼現在還能拿嗎？誰來負責廢除和審核？

從例（10）可見，政府在撰寫政策文本時省略主語，並默認讀者知曉動作執行者是“相關政府職能部門”。而例（11）零形回指對於企業意味著執行主體的“隱匿”，那麼企業面臨如跨市收費、補貼發放等實際問題時，主體缺位導致他們不知道向“誰”尋求救濟。這也解釋了為何廣清產業園需要專門成立“五大服務專班”來協調解決“路燈遷改、燃氣接駁”等問題，歸根結底是因為政策文本的話語斷裂，零形回指使用錯誤導致主體缺位，所以園區必須單獨安排線下的人工服務來補位。這種話語斷裂無疑增加了人工成本，也讓企業找不到門路，訴求得不到及時地解決。

**（三）間接回指語義錯位——政企在營商環境需求層級上的認知落差**

間接回指是語篇中兩個不同運算式指稱不同但相關事物的語言現象，間接回指中先行語的形式繁多，可以是名詞或者名詞短語，也可以是從句或句子（劉宇楠，關碧瑩，2016）。當政企雙方依賴不同的認知框架進行推理時，便會產生語義錯位，如例：

（12）政策文本：清遠推廣學習廣州經驗……優化生活配套設施，推進清遠成為廣州的休閒花園。

（13）泰亞科技副總經理柯永傑指出：“現在基地有 400 人左右，計畫擴充到 500 人，雖然仍有缺口，但住宿和通勤問題在一步步完善。”

（14）企業回饋：招工太難了，園區的住宿和公交班車跟不上。

例（12）中的“生活配套設施”（先行語）是一個集合名詞，政府的認知框架可能偏向於“環境、高標準醫療和休閒設施”的宏觀願景，而例（13）和例（14）的企業在使用“住宿、通勤、公交班車”（回指語）來回指這一概念時，聚焦的是最底層的生存與生產保障。因此如果不加以話語調適來彌補這種落差感，將會直接影響企業的獲得感和政策效能。

## 六、基於語篇回指優化的營商環境治理建議

針對上述分析，本文從語篇回指優化的角度，為深化廣清一體化營商環境建設，提出以下三條治理建議：

第一，縮短指稱距離，推行“白話版”政策語篇。即政府應減少長篇幅、多層級的代詞回指，避免使用“該項”、“其”和“此”等抽象指稱。在出臺涉及審批、補貼、稅收等專業性較強的政策時，應配套發佈“政策圖解”或“白話版導讀”，將抽象概念轉化為具象的實體回指。例如，不只說“探索建立公平互惠的稅收分成制度並推廣至其他合作共建園區”，而是直接列明：“本政策適用於清城區、清新區的 XX 產業園和 XX 工業園。”

第二，明確零形回指的隱藏主體，建立清晰的權責話語體系。即在制定涉及審批、補貼、處罰等政務服務細則時，應儘量減少“Ø”式主語省略，改用明確的名詞或機構名稱作為主語。例如，將“（Ø）簡化註銷流程”修改為“由清遠市市場監管統一受理企業註銷申請”。

第三，發揮“幫辦導辦”的語用仲介作用，構建政企共用的“回指對齊”機制。即應充分利用廣清產業園已有的“幫辦導辦專窗”和“廣清茶話薈”等成功互動平臺，將其從線下服務延伸為語用橋樑。具體而言，可將企業高頻諮詢的員工住宿、公交班車（回指語）系統收集整理，反向映射到政策文本中的生活配套設施和要素保障（先行語），建立“政企共建共用的營商環境語料庫”，消除語義內涵錯位造成的溝通障礙。

## 七、結語

廣清一體化的本質不僅是地緣、產業和體制的融合，更是兩地政企話語的深度交融。本

文基於語篇回指的切入，研究發現，清遠市政企話語在辭彙回指和人稱回指上實現了高度協同，在微觀政策執行中，因代詞回指指稱跨度大、零形回指主體缺位以及間接回指語義錯位三重障礙導致政策傳導不暢、企業獲得感不足。故此提出的“縮短指稱距離、明確執行主體、構建回指對齊機制”三條建議，旨在為清遠市優化政策文本表達、提升“廣清通辦”與“幫辦導辦”服務效能提供可操作的話語策略。由於目前語料主要集中於廣清產業園，結論的普適性有待進一步驗證。未來可擴展至清遠其他產業園區及更廣泛的企業類型，並結合問卷調查、深度訪談等方法，深化對政企話語斷裂成因與後果的量化分析，為打造“清遠成本、廣州服務”的營商環境品牌提 供更堅實的實證支撐。

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# Synergy and Fragmentation: An Empirical Study on the Government-Business Discourse in the Guangqing Integrated Business Environment

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**Abstract:** The optimization of the business environment is not merely a process of institutional refinement improvement but also one of discourse interaction and meaning construction between the government and businesses. Taking discourse anaphora as the theoretical framework, this study constructs a self-built corpus consisting of Qingyuan's business environment policy texts and corporate feedback from the Guangqing Industrial Park. Employing corpus-based quantitative analysis and cognitive-pragmatic methods, it empirically examines the mechanisms of synergy and fragmentation in government-business discourse in the context of Guangqing Integration. The study finds that both government and businesses achieve a high degree of discourse synergy at the macro-level objectives through lexical anaphora; however, at the level of micro-policy implementation, there are three anaphoric problems that lead to obvious discourse fragmentation: wide referential span in pronominal anaphora, subject absence in zero anaphora, and semantic misalignment in bridging anaphora. Accordingly, this study proposes three discourse optimization strategies: shortening referential distance, clarifying the executing subject,, and establishing an anaphoric alignment mechanism, so as to provide pragmatic strategies and practical suggestions for further improving the business environment in Qingyuan.

**Keyword:** business environment; discourse anaphora; Guangqing Integration; government-business discourse; discourse synergy and fragmentatio.

# AI賦能下的《電子商務數據分析》課程體系重構*

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**摘要:**針對AI時代《電子商務數據分析》課程存在的體系滯後、AI內容缺失等問題,提出“雙主線、模組化、人機協同”課程重構方案:以電商數據分析全流程為明線、AI賦能為暗線,開發模組化“教學積木”,設計人機協同教學模式與智能評價體系,旨在破解學生“學過難用”困境,實現從“工具鏈”向“智能環”的轉變,為培養“懂AI、通業務、能落地”的高素質人才提供可複製的改革路徑。

**關鍵詞:**電子商務數據分析;課程重構;雙主線;人機協同

## 一、研究背景與現狀

### (一)研究背景

隨著我國數字經濟進入高質量發展階段,人工智能技術的深度嵌入正快速重塑電商數據分析崗位的能力模型,傳統基於Excel的基礎統計與簡單圖表製作逐步被智能預測、用户畫像、評論情感分析、推薦系統等AI驅動任務所替代,企業對電商人才的技能要求已從“會使用分析工具”升級為“能理解業務邏輯、調用AI模型、解讀分析結果、輔助商業決策”的複合素養。在此背景下,國家職業教育改革持續推進,《國家職業教育改革實施方案》明確“三教”改革任務並啟動“1+X”證書制度,“電子商務數據分析”被納入第二批“1+X”證書,2022年教育部進一步要求推動人工智能在教育教學中的深度應用,2024年全國教育工作會議提出“實施人工智能賦能職業教育行動”;然而,當前高職院校電子商務數據分析課程普遍存在教學資源更新滯後、實踐專案脱離企業真實場景、學生個性化學習支持不足、評價方式單一等問題,亟需通過AI技術實現從“經驗驅動”向“數據驅動”的教學範式轉變。因此,本研究以AI賦能為主線,探索電子商務數據分析課程體系的重構路徑,以培養適應數字經濟時代的高素質技術技能人才。

### (二)研究現狀

國內《電子商務數據分析》課程的研究現狀可從以下四個方面加以概括:在政策回應層面,課程改革緊密對接國家職業教育“1+X”證書制度,王福紅(2025)[1]、曹毅(2022)[2]等學者通過將職業技能等級標準拆解為課程模組或重構教學單元,實現“課證融通”;胡現玲(2025)[3]、李婧(2023)[4]進一步構建“崗位解構—內容重構—競賽融入—證書銜接”的閉環路徑。在教學模式創新層面,線上線下混合式教學已成為主流形態,韓秀枝(2023)[5]基於OBE理念構建“線上預習—線下互動—課後實訓”框架,武悦[6](2023)驗證其可有效提升Python等工具的應用能力;專案驅動與案例教學作為實踐教學的核心載體,郭炬(2024)[7]、周婕(2025)[8]將“雙十一數據分析”等企業真實專案轉化為教學案例,強化學生的團隊協作與問題解決能力;同時,殷蘭波(2025)[9]提出的基於數字畫像的學生能力評價體系,為個性化精准教學提供了初步支撐。在技術融合應用層面,課程改革正從“工具應用”向“技術賦能”轉型,張華瓊(2024)[10]、林楚迪(2022)[11]主張將機

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器學習、智能推薦演算法納入教學內容，鄭詩蔓（2025）[12]實踐了Kimi的AI智能指導與Power BI自動化可視化等AI工具輔助教學,張華（2024）[13]提出的“AI認知—工具應用—實戰創新”能力鏈，構成了AI賦能課程的技術框架。在育人目標拓展層面，課程已從單一技能培養走向“知識+技能+價值”三位一體，梅童（2025）[14]構建了以“數據倫理”為核心的“1+6+1”課程思政體系，李愛雄（2025）[15]結合電商崗位特點挖掘“數據真實”“隱私保護”等思政要點，崔珍珍、張華（2025）[16]等驗證了通過案例教學與情景討論實現價值引領的有效性；同時，權李之,王洋（2023）[17]強調打破學科壁壘，將數據分析與電商運營、市場行銷等深度融合，培養“數據分析能力+業務理解能力”的複合型人才。

### （三）已有研究實踐基礎及缺口

綜合現有研究成果可見，《電子商務數據分析》課程教學改革已形成“政策引領、模式創新、技術賦能、價值引領”的實踐基礎。然而，現有研究仍存在明顯缺口，一是尚未系統構建AI賦能的課程內容體系，多數研究仍局限於傳統數據分析流程（採集—清洗—分析—可視化）或基礎軟體工具的教學，未將機器學習演算法、深度學習模型、自然語言處理等人工智能核心技術作為課程核心模組加以整合；二是課程內容與AI技術存在“兩張皮”現象，一方面核心知識點仍聚焦傳統方法，對AI演算法原理、模型構建及業務落地涉及甚少，學生難以形成AI驅動的數據分析思維，另一方面少數涉及AI的研究僅停留於概念介紹或工具演示層面，未能將AI技術與電商真實業務場景及數據分析任務深度融合，導致學生雖知曉工具名稱卻無法運用AI解決實際問題。

## 二、研究思路及目標

“電子商務數據分析”是電子商務專業應對人工智能時代數位化轉型的核心課程。課程秉持“崗課賽證”綜合育人理念，全面落實職業教育國家教學標準，緊扣電商數據分析崗位的智能化升級要求，深度融合電子商務技能大賽中的AI數據分析賽項內容，引入“1+X”電子商務數據分析職業技能等級證書（中級）標準，以校企合作的最新電商運營專案為載體，在AI賦能背景下以“商業問題驅動、人機協同分析”為主線，按照“數據維度由單到多、AI工具由淺入深、業務場景由簡到繁”的原則，

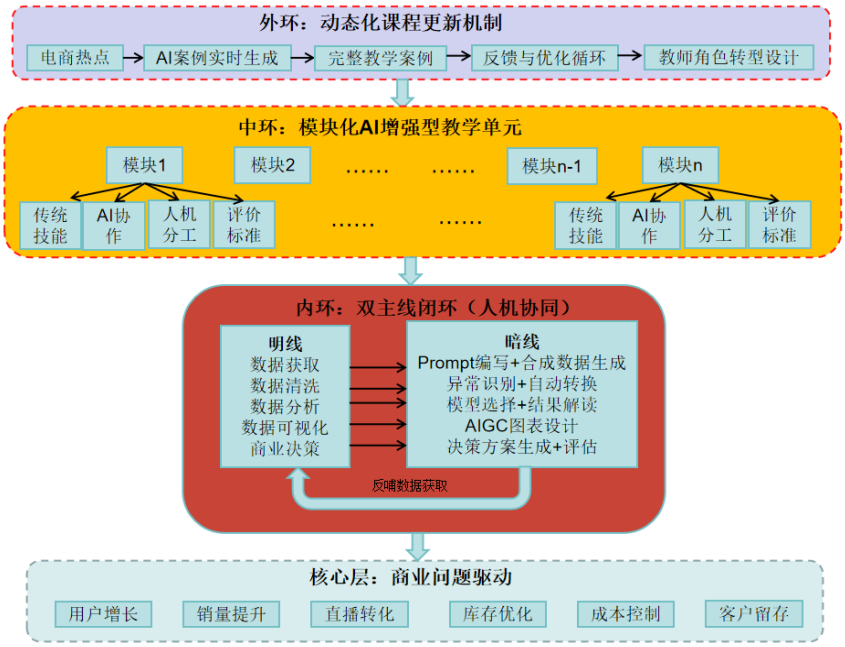


圖1 智能課程體系圖

將傳統按數據分析流程線性展開的“工具鏈”式內容，重構為“雙主線並行（電商流程明線+AI賦能暗線）、模組化組合（N個AI增強型教學積木）、人機協同實踐”的新型課程體系（圖1）。每個教學積木均是一個完整的“微專案”，包含傳統技能目標、AI協作目標、具體任務、人機分工指南與評價標準，學生在看似重複的分析過程中，逐步掌握“向AI描述業務問題、調用AI模型、解讀AI結果、輔助商業決策”的複合能力，從根本上解決了學生“好像學過演算法、好像會調工具、好像能分析”的“三好”現象。課程同步實施“三線融通”教學策略：一是思政貫穿，誠信立人——通過演算法公平性討論、數據倫理案例、國產AI工具認知，引導學生樹立科技向善的價值觀；二是人機協同，AI賦能——明確AI助手與人的分工邊界，培養學生“業務判斷+AI協作”的核心素養；三是理實貫通，實戰育人——依託動態更新的真實脫敏數據集與智能案例生成器，實現教學內容與電商行業熱點的即時同步。通過上述重構，綜合培養電子商務行業數據分析崗位“懂AI技術、通電商業務、能協同落地”的德技兼備數位化技術技能人才。

## 三、課程體系重構具體措施

### （一）重構“雙主線、模組化”教學內容

一方面，專業教師需密切關注人工智能技術在電商數據分析領域的最新應用動態，主動學習機器學習、自然語言處理、智能推薦等AI前沿知識，掌握人機協作的教學設計與實施方法。另一方面，制定面向AI賦能的專業教學標準和人才培養方案，結合電子商務技能大賽（含AI數據分析賽項）和“1+X”電子商務數據分析職業技能等級標準（中級）中新增的“數據挖掘與機器學習應用”模組，實現“崗課賽證”高度融合，構建以“雙主線、模組化”為特徵的數位化能力教學內容。

具體而言，課程打破傳統“數據採集→處理→分析→可視化”線性展開的“工具鏈”式結構，重構為“明線+暗線”並行的雙主線邏輯。明線為電商數據分析全流程，即“數據獲取→數據清洗→數據分析→數據可視化→商業決策”，確保學生掌握從原始數據到商業洞察的核心技能框架；暗線為AI賦能的關鍵節點與方法論，在明線的每一個關鍵節點系統性嵌入AI協作技能——數據獲取環節嵌入“AI輔助爬取Prompt編寫”與“AI合成數據生成與評估”，數據清洗環節嵌入“AI助手自動識別數據異常與類型轉換”，數據分析環節嵌入“向AI描述業務問題選擇模型”與“AI模型結果的可視化解讀與業務轉化”，數據可視化與報告撰寫環節嵌入“AIGC輔助圖表設計與報告生成”。基於雙主線邏輯，將課程內容打散重構成一系列獨立的“教學積木”，每個積木包含傳統技能目標、AI協作目標、具體任務、人機分工指南和評價標準，覆蓋用户畫像構建、銷量預測、購物籃分析、評論情感分析等不少於15個典型業務場景，實現教學內容的模組化、可重組與AI深度嵌入。

### （二）精准學情分析與目標定位

AI賦能時代，基於大數據與人工智能技術精准分析學生學情，充分發揮智能育人作用。借助線上測試，通過智慧教學平臺全過程採集學生學習行為數據，利用智能分析軟體或AI助教自動生成學生整體和個體學情報告，形成學生成長診斷報告。

針對AI賦能下的《電子商務數據分析》課程，制定班級學生成長診斷報告：從班級整體角度，分析學生前續課程養成能力、知識和技能基礎、認知和實踐能力、學習特點等四個維度；同時分析班級個體差異。依據電子商務數據分析崗位職責、專業標準、課程標準、職業技能等級標準，校企共同制定三維教學目標，明確教學重點，結合學情預判教學難點，為後續精准教學提供依據。

### （三）構建人機協同教學模式

革新傳統教學模式，按照教育數位化轉型戰略，樹立AI賦能思維，充分運用智慧教學

平臺和智能數字技術，構建“雙師共育、三階遞進”的人機協同數位化教學模式。課程遵循“商業問題驅動、人機協同分析”的工作流程，依據知行合一的認知規律，將“識數據—精技術—會分析—優方案—擅實戰”五個關鍵環節貫穿到教學實施全過程，同時在每個環節嵌入AI協作技能。課前，通過智慧平臺推送AI預習資源，學生線上自主學習，AI分析預習數據並生成學情報告，教師針對性備課；課中，實施“雙師課堂”，按照“導任務（商業問題）、定目標（人機分工）、演過程（AI工具演示）、練技能（學生實操）、優方案（AI輔助優化）、評收穫（人機協作複盤）”六個環節，螺旋式培養學生AI協作崗位職業能力；課後，利用智慧平臺拓展任務（如使用AI生成新案例），學生完成分層作業，AI自動批改並提供回饋，深化學習，提升創新能力。同時，按教學環節融入思政元素，引導學生將AI倫理意識內化為職業品德，以學思踐悟促知行合一，實現德技並修。

依據AI賦能課程特徵，剖析電子商務數據分析相關崗位需求，明確崗位知識、能力、素養要求，構建“三元五維”數位化智能綜合評價體系，即校內教師、企業教師和學生對理論知識、專業技能、人機協作、團隊合作、職業素養五個維度的評價，形成智能評價與主觀評價相結合的過程評價。

## 四、總結

本研究立足於數字經濟與人工智能技術深度融合的時代背景，針對《電子商務數據分析》課程現有教學體系中AI核心模組缺失、課程內容與前沿技術“兩張皮”、學生複合型分析能力培養不足等突出問題，系統梳理了國內在政策回應、教學模式創新、技術融合及育人目標拓展等領域的研究進展，明確了以AI賦能驅動課程體系重構的迫切性與理論依據。基於“崗課賽證”綜合育人理念，研究構建了“雙主線並行、模組化組合、人機協同實踐”的新型課程體系：以電商數據分析全流程為明線，以AI賦能關鍵節點與方法論為暗線，將課程內容重組為系列“教學積木”，每個積木涵蓋傳統技能目標、AI協作目標、具體任務、人機分工指南及評價標準；同步建立基於智慧教學平臺的學情精准分析機制、“雙師共育、三階遞進”的人機協同教學模式以及“三元五維”智能綜合評價體系。實踐表明，該課程體系有效破解了學生“好像學過演算法、好像會調工具、好像能分析”的“三好”困境，實現了從傳統“工具鏈”向“智能環”的根本轉變。通過思政貫穿、人機協同與理實貫通的三線融通策略，課程達成了知識傳授、能力培養與價值引領的協同育人目標，為培養“懂AI技術、通電商業務、能落地實踐”的高素質數位化技術技能人才提供了系統化的改革路徑，亦為職業教育領域同類課程的智能化轉型提供了可複製、可推廣的理論參考與實踐範例。

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# AI-Empowered Reconstruction of the Curriculum System of E-commerce Data Analysis

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**Abstract:** To address the issues of curriculum system lag and lack of AI content in the E-commerce Data Analysis course in the AI era, this paper proposes a curriculum reconstruction scheme featuring "dual main lines, modularization, and human-machine collaboration". Specifically, the scheme takes the complete process of e-commerce data analysis as the explicit main line and AI empowerment as the implicit main line, develops modular "teaching building blocks", and designs a human-machine collaborative teaching model and an intelligent evaluation system. It aims to resolve the dilemma where students "have learned but find it difficult to apply", achieve a transformation from "tool chain" to "intelligent loop", and provide a replicable reform path for cultivating high-quality talents who "understand AI, master business, and are capable of implementation".

**Keywords:** E-commerce data analysis; Curriculum reconstruction; Dual main lines; Human-machine collaboration

# 《亞太經濟管理學刊》徵稿啟事

《亞太經濟管理學刊》（Asia Pacific Business and Economics，APBE，ISSN(Print): 3135-3681、ISSN(Online): 3135-369X）由香港科教出版社有限公司主辦。本刊立足亞太、面向全球，以打造亞太地區經濟管理研究的高端學術陣地、搭建學術交流的優質橋樑為核心定位，聚焦全球經濟變革與管理創新前沿，深耕亞太區域經濟發展與企業管理實踐，致力於傳播前沿研究成果、推動理論創新與實踐融合，為亞太乃至世界經濟管理領域的學術研究、政策制定與企業發展提供智力支持。現常年面向全球經濟管理學者、高校師生、行業專家、研究人員徵集優質文稿，誠邀各界同仁惠賜佳作。具體徵稿事宜如下:

## 一、欄目設置與收錄範圍

### （一）經管前沿

聚焦數字經濟、智能經濟、產業集聚、產業升級、供應鏈管理、綠色低碳經濟、經濟發展、企業戰略等前沿議題，收錄理論創新、模型科學、方法新穎、論證嚴謹的學術論文。

### （二）AI與經濟

圍繞人工智能技術、大數據分析、智能決策、智能行銷、AI 服務與消費者行為、人工智能賦能經濟轉型、智能治理等方向，收錄實證研究、機制探討、應用分析類學術成果。

### （三）數字商貿

涵蓋數字貿易、跨境電商創新、數字產業升級、數字平臺治理、數據要素流通、跨境數字服務貿易、電子商務生態等領域，收錄理論與實踐相結合的學術論文、調研報告、案例研究。

### （四）區域經濟發展

關注亞太區域經濟合作、國際貿易格局、全球價值鏈、區域產業鏈、自貿區建設、“一帶一路”經貿合作、城市群經濟協調發展、區域經濟一體化等議題，收錄國際視野、比較研究、政策分析類論文。

### （五）管理理論與實踐

覆蓋公司治理、組織行為、人力資源管理、財務管理、市場行銷、風險管理、公共管理、經濟治理、營商環境優化、產業規制等研究方向，收錄兼具理論價值與實踐指導意義的學術論文、研究綜述。

### （六）綜述與書評

關注經濟管理學科前沿動態、學術熱點、重要學術會議綜述、經典著作評介、研究方法評述、學科發展趨勢研判等內容，收錄高質量學術綜述、書評、研究述評。

## 二、投稿指南

### （一）稿件基本要求

本刊徵集中英文原創性研究稿件，字數以6000-13000字為宜。

稿件語言表達準確規範，邏輯清晰，文字簡潔流暢，專業術語使用統一規範，同一概念在全文中表述一致；英文稿件應符合學術英語表達習慣，語法準確、邏輯流暢、術語統一。

稿件宜具備以下核心框架，確保層次清晰、邏輯嚴密：引言、文獻綜述、研究方法、研究結

果、討論與結論。

來稿應具備鮮明的經濟管理學科理論性、創新性、應用性，做到立論科學、觀點鮮明、論據充分，層次分明、邏輯嚴謹、預見準確。

**（二）學術規範與倫理要求**

投稿論文須為作者原創，未在任何期刊、會議論文集、網路平臺或其他公開載體發表。嚴禁一稿多投、抄襲、剽竊、數據偽造等學術不端行為。

若論文系作者已發表成果的延伸或深化研究，須在投稿時主動說明與已發表成果的關聯與區別，並標注新增內容與創新之處，由編輯部判斷是否符合原創性要求。

作者需保證稿件未侵犯他人著作權。如經查實稿件存在侵犯他人著作權的情況，本刊將立即撤稿，由此引發的侵權糾紛及法律責任，均由作者自行承擔，與本刊無關。

凡在研究或寫作過程中使用過生成式AI工具的，作者須在稿件中以註腳或專項聲明形式如實披露，說明所使用工具的名稱、用途及範圍。作者對生成內容的準確性、原創性及倫理合規性承擔全部責任。本刊保留對稿件進行 AI 生成內容檢測的權利，檢測結果將作為審稿依據之一。

## 三、投稿說明

**（一）投稿方式與審稿流程**

來稿一律採用Word格式文檔，不接受PDF及其他類型文檔，稿件格式須嚴格遵照本刊要求執行。

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凡向本刊投稿的作者，均視為同意著作權許可使用協議，授權本刊享有對文章進行編輯、修改、出版、複製、傳播及授權第三方使用等相關權利，本刊不再另行支付著作權使用費；作者保留署名權及其他合法權益。

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**附件**

# 《亞太經濟管理學刊》稿件格式要求

來稿格式參考學術類經管文章規範，具體要求如下：

## 一、基本要求

稿件內容需包含：題目、作者姓名、單位、摘要、關鍵字、正文及參考文獻。中文稿件須同時提供對應的英文題名、摘要及關鍵字。以下各項要求對中英文稿件均適用；英文稿件可通篇使用Times New Roman字體。

## 二、文稿題目

題名採用黑體三號字。以簡潔、準確的詞語反映論文核心內容，避免籠統表述、非公知符號、代號及縮略詞；標題不超過20字，一般不設副標題。中英文題名含義保持一致。

基金專案：凡屬國家及省、部級等各類基金專案資助的論文，需在文稿首頁予以說明。批准號用（）括起。標題右上角標注*，頁下注宋體五號字，專案名稱應按國家有關部門規定的正式名稱填寫；多項基金專案應依次列出，其間用分號分隔並標注專案批准號。

## 三、文稿署名

作者姓名：宋體四號字；單位、郵編：宋體五號字。姓名、單位各單列一行，單位需注明全稱、國家、城市、郵編（括弧標注）。多位作者分屬不同單位時，姓名右上角、單位前標注對應序號。

正文末尾附第一作者與通信作者簡介（宋體五號字）：姓名、性別、單位（至二級單位）、職稱、最高學位、研究方向、聯繫電話、電子郵箱。

## 四、摘要與關鍵字

“摘要”：黑體小五號加粗；摘要內容：楷體小五號字。第三人稱撰寫（不用“本文”），含研究目的、方法、核心結果與結論，字數200—300字，不引用公式、文獻及非公知符號。

“關鍵字”：黑體小五號加粗；關鍵字內容：楷體小五號字。選詞規範，優先取自標題與正文，3—5個為宜。

## 五、文稿正文

正文統一宋體五號字，固定值20磅行距；正文內數字、英文統一用Times New Roman。論述邏輯清晰、數據可靠、語言精練、行文流暢。

## 六、層次標題

一級標題：黑體小四號加粗，段前段後6磅；序號：一、

二級標題：楷體五號加粗，段前段後3磅；序號：（一）

三級標題：宋體五號加粗；序號：1.

各級標題首行縮進2字元；英文稿件層級：1、1.1、1.1.1……

## 七、計量單位與外文符號

物理量、計量單位符合國際標準；區分外文文種、字體、大小寫，上下標清晰規範。

## 八、圖表規範

圖表精簡凝練、避免冗餘重複；具備獨立自明性，規範標注圖序、圖名、表序、表名。

圖：圖序、圖名置於圖下方，宋體小五號加粗、居中

表：表序、表名置於表上方，宋體小五號加粗、居中

## 九、參考文獻

參考文獻表置於文末，本刊採用順序編碼法著錄參考文獻，僅列入作者親自閱讀、明確引用且公開發表或有案可查的文獻。參考文獻按其在文內出現的先後順序編號，並在文內對應位置右上角注明序號。主要責任者在3名以內的，全部列出；超過3名時，在第3名後面加“等．”。主要格式如下：

（1）專著、論文集、學位論文、報告：[序號]主要責任者．文獻題名[文獻類型標誌]．出版地：出版者，出版年：起止頁碼．

（2）期刊文章：[序號]主要責任者．文獻題名[J]．刊名，年，卷(期)：起止頁碼．

（3）專著、論文集中析出文獻：[序號]析出文獻主要責任者．析出文獻題名[文獻類型標誌]//原文獻主要責任者．原文獻題名．出版地：出版者，出版年：析出文獻起止頁碼．

（4）專利：[序號]專利所有者．專利題名[P]．專利國別：專利號，出版日期．

（5）電子文獻：[序號]主要責任者．電子文獻題名[電子文獻類型標誌／載體類型標誌]．電子文獻的出處或可獲得的地址，發表或更改日期／引用El期(任選)．(注①文獻類型標誌：M一專著，C一論文集，J一期刊，D一學位論文，R一報告，S一標準，P一專利。②電子文獻類型標識：BD一資料庫，CP 一電腦程式，EB一電子公告。③載體類型標識：MT 一磁帶，DK一磁片，OL 一聯機網路。)

外文文獻著錄規則同上。外國人名，姓在前，全部大寫；名用縮寫在後，不加縮寫點。

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