

Promotion Mechanism and Effectiveness Evaluation of Low-Carbon Products on E-Commerce Platforms Under the Guidance of Green Consumption

Qianwen Lv

School of Finance, Fushun Vocational Technology Institute, Fushun 113122, Liaoning, China

Corresponding author: Qianwen Lv (e-mail: m18642326699@163.com)

ABSTRACT Against the background of the dual-carbon goal and the popularization of green consumption, e-commerce platforms have become a key hub connecting low-carbon product supply and consumer demand. A systematic promotion mechanism directly affects the implementation of the low-carbon economy and the activation of the consumer market. Based on the theory of planned behavior, the technology acceptance model, and collaborative governance theory, this paper constructs a four-in-one analytical framework of "subject-strategy-environment-effect." It systematically analyzes the core connotation, constituent elements, and operational logic of low-carbon product promotion mechanisms on e-commerce platforms under the guidance of green consumption. Empirical research is conducted using questionnaire survey, case analysis, structural equation modeling, and difference-in-differences models, combined with practical data from typical platforms such as Tmall, JD.com, Pinduoduo, and NetEase Yanxuan. A promotion effectiveness evaluation system is constructed from four dimensions: economy, environment, society, and mechanism operation. The study quantitatively analyzes the influence paths and strengths of different promotion strategies, subject collaboration models, and policy environments on promotion effectiveness.

INDEX TERMS green consumption, e-commerce platform, low-carbon products, promotion mechanism, effectiveness evaluation

I. INTRODUCTION

A. RESEARCH BACKGROUND

GLOBAL climate governance and sustainable development have become core issues in the international community. China has clearly put forward the strategic goal of "peaking carbon emissions before 2030 and achieving carbon neutrality before 2060", and low-carbon transformation has become a necessary path for high-quality economic and social development. As a key link in carbon reduction, the consumer end has enormous potential for green transformation, driving a shift in demand from "quantity satisfaction" to high-quality, eco-friendly fabrics that align with environmental protection goals. Data shows that by 2024, the scale of China's green consumption market will exceed 7 trillion yuan, with online consumption of low-carbon products accounting for 42.3%. E-commerce platforms, with their wide coverage, low transaction costs, abundant data resources, and strong interactivity, have become the core carriers of low-carbon product circulation [1,2].

B. PRACTICAL SIGNIFICANCE

Firstly, provide operational promotion mechanism optimization solutions for e-commerce platforms, helping them accurately match consumer needs, optimize strategy combinations, reduce promotion costs, and enhance the efficiency and market competitiveness of low-carbon product promotion. Secondly, provide marketing strategy guidance for low-carbon enterprises, assisting them in optimizing sustainable fiber applications, green market entry points, and collaborative platform mechanisms to maximize market penetration and brand influence [3].

II. THEORETICAL BASIS AND CONSTITUENT ELEMENTS OF LOW-CARBON PRODUCT PROMOTION MECHANISM ON E-COMMERCE PLATFORMS UNDER THE GUIDANCE OF GREEN CONSUMPTION

A. DEFINITION OF CORE CONCEPTS

The Technology Acceptance Model was proposed by Davis in 1989, which states that perceived usefulness and perceived ease of use are key factors influencing users' acceptance of new things (products, technologies, services).

Perceived usefulness and perceived ease of use ultimately determine actual usage behavior by influencing usage attitudes and intentions. Applying it to the promotion and research of low-carbon products, the perceived usefulness is reflected in consumers' awareness of the environmental benefits, performance, and long-term value of low-carbon products; Perceived ease of use is reflected in the convenience of consumers in the process of purchasing low-carbon products (such as platform search, purchase process), and the difficulty of information acquisition (such as product environmental attribute description). E-commerce platforms can promote consumer acceptance and purchase of low-carbon products through strategies such as information disclosure (enhancing perceived usefulness) and channel optimization (enhancing perceived ease of use) [4,5].

This study defines "low-carbon products" as "products that have reduced their lifecycle carbon emissions by $\geq 20\%$ compared to traditional products in the same category (covering the entire process of raw material mining, production and processing, logistics transportation, use, and waste disposal in carbon footprint accounting) and comply with national/industry green certification standards (such as GB/T 23331 Energy Management System, ISO 14064 Carbon Footprint Accounting Standard)" [6].

For low-carbon products, it is further refined:

Clothing category: Carbon emissions per unit product $\leq 30\text{kgCO}_2\text{eq/piece}$;

Fabric category: Carbon emissions per unit product $\leq 5\text{kgCO}_2\text{eq/m}$.

B. COMPONENTS OF PROMOTION MECHANISM

The promotion mechanism of low-carbon products on e-commerce platforms under the guidance of green consumption is a complex organic system, consisting of three dimensions: core subjects, strategic tools, and supporting environment. These elements interact and influence each other, jointly determining the operational efficiency and effectiveness of the promotion mechanism.

The four in one integrated analysis framework of "subject-strategy-environment-effect" integrates three core theories, with clear connotations of each dimension:

1. Subject dimension: Covers core participants such as e-commerce platforms, low-carbon product enterprises, consumers, and governments, clarifying the rights and responsibilities of all parties based on collaborative governance theory;

2. Strategy dimension: Includes five types of strategic tools (price incentives, information disclosure, channel optimization, social communication, scenario marketing), optimizing strategy design based on the technology acceptance model to enhance user acceptance;

3. Environment dimension: Comprises three supporting environments (policy environment, technical environment, social environment), constructing an adaptive environment based on system theory;

4. Effect dimension: Evaluates promotion effects from four aspects (economic effect, environmental effect, social effect, mechanism operation effect), verifying behavior-oriented effects based on the theory of planned behavior [7].

C. CORE SUBJECT

The core entities of the promotion mechanism include e-commerce platforms, low-carbon product enterprises, consumers, government departments, as well as auxiliary entities such as industry associations, third-party certification agencies, and social organizations. The role positioning and functions of each entity are as follows:

Low carbon product enterprises: product suppliers are the fundamental support for promotion mechanisms.

Specific responsibilities include: conducting research and development of low-carbon technologies and product innovation, ensuring product quality and environmental performance; Cooperate with the platform to complete green certification and information disclosure; Provide product related information (carbon footprint data, environmental performance specifications) and service support; Jointly carry out promotional activities with the platform, share costs and benefits [8-10].

D. STRATEGY TOOLS

Strategic tools are specific means for e-commerce platforms to promote low-carbon products. Based on existing research and practical experience, they can be divided into five categories: price incentives, information disclosure, channel optimization, social communication, and scenario marketing

Price incentive strategy: By reducing consumer purchasing costs to stimulate consumption willingness, including platform subsidies (direct cash reduction, full discount activities), coupon distribution, green point redemption (accumulating points for purchasing low-carbon products, redeeming goods or deducting cash), tiered discounts (the more purchased, the greater the discount), trade in (traditional products are subsidized for exchanging low-carbon products), etc. [11].

Scenario marketing strategy: Stimulate potential consumer demand, narrow the "knowledge-action gap", including building consumption scenarios (such as "low-carbon homes", "green offices", "environmentally friendly travel" scenarios), creating themed activities (such as "green life festivals" and "low-carbon consumption months"), immersive experiences (such as online virtual experiences of low-carbon product usage effects, offline experience activities), etc. [12-14].

E. SUPPORTING ENVIRONMENT

The supporting environment is the external condition for the effective operation of the promotion mechanism, including three dimensions: policy environment, technological environment, and social environment

Policy environment: including low-carbon product certification standards, carbon footprint accounting methods, government subsidy policies, tax incentives, regulatory systems, industry self-discipline norms, etc., providing institutional guarantees and policy support for the operation of promotion mechanisms.

Technical environment: including big data analysis, artificial intelligence, blockchain, Internet of Things and other technologies, supporting the platform to achieve precise marketing, information tracing, carbon footprint accounting, user profile construction and other functions, improving promotion efficiency [15,16].

Social environment: including green consumption culture, social identity, environmental protection publicity and education, consumer green awareness level, etc., providing a good social atmosphere for the operation of promotion mechanisms. The core components of the low-carbon product promotion mechanism on e-commerce platforms are shown in Table 1:

III. THE OPERATIONAL LOGIC OF PROMOTING LOW-CARBON PRODUCTS ON E-COMMERCE PLATFORMS UNDER THE GUIDANCE OF GREEN CONSUMPTION

A. SUBJECT INTERACTION RELATIONSHIP

1) Interactive Relationship between Platform and Enterprise
E-commerce platforms and low-carbon product enterprises form a strategic partnership of "cooperation and win-win", and their interactive logic is reflected in "resource complementarity - risk sharing - benefit sharing". The platform provides sales channels, traffic support, promotion tools, data services, and brand endorsement for enterprises, helping them reduce market development costs, accurately grasp consumer needs, and enhance product exposure; Enterprises provide high-quality low-carbon products to the platform, enrich the supply of green products on the platform, and enhance the platform's green image and differentiated competitiveness [17]. For example, Tmall provides a platform subsidy of up to 20% and traffic tilt for low-carbon product companies to settle in, while companies need to publicly disclose their product carbon footprint data and commit to environmental performance. The two sides jointly carry out the "Green Life Festival" activity, share promotion costs and sales revenue [18,19].

2) Interactive Relationship between Platform and Consumers

The interaction relationship between the platform and consumers is "service supply demand satisfaction feedback optimization". The platform meets consumers' green consumption needs and enhances their consumption experience through diversified promotion strategies; Consumers provide market information to the platform through purchasing behavior, evaluation feedback, and demand expression, helping the platform optimize promotion strategies and service quality. The specific interaction methods include: the platform

analyzes consumer behavior preferences through big data to achieve accurate recommendations and personalized services; Consumers provide feedback on product and service issues through evaluations, complaints, surveys, and other means; The platform carries out interactive promotional activities (such as low-carbon lifestyle challenges, environmental knowledge quizzes) to enhance consumer participation; Establish a consumer rights protection mechanism on the platform, resolve consumer disputes, and enhance consumer trust. For example, NetEase Yanxuan collects consumer demand and suggestions for low-carbon products through user communities, optimizes product design and promotion strategies; Consumers who share their experience of using low-carbon products can receive green point rewards, forming a virtuous cycle of "consumption sharing incentive re-consumption" [20,21]. The comparison of low-carbon product promotion mechanisms between integrated e-commerce platforms and vertical e-commerce platforms is shown in Table 2:

3) Interaction between the Government and Other Entities

The interactive relationship between the government, platforms, enterprises, and consumers is "policy guidance behavior response feedback optimization". The government guides the behavior of all parties through policy tools to provide institutional guarantees for the operation of the promotion mechanism; Platforms, enterprises, and consumers respond to policy requirements through behavior, while providing feedback to the government on policy implementation effectiveness and actual needs, promoting policy optimization. The specific interaction methods include: the government providing promotion subsidies and tax incentives to the platform to encourage it to promote low-carbon products; The government provides subsidies for low-carbon technology research and certification to enterprises, encouraging them to supply high-quality low-carbon products; The government guides consumers to participate in green consumption through publicity and education; Platforms, enterprises, and consumers provide feedback to the government through industry associations and public participation channels on issues in policy implementation, such as inconsistent certification standards and cumbersome subsidy application processes, to promote policy adjustments. For example, some local governments provide subsidies of 50-100 yuan per ton of carbon emissions reduction for low-carbon product promotion activities on e-commerce platforms. The platforms will partially benefit consumers and enterprises from the subsidies to enhance the promotion effect; The government simplifies the subsidy application process and improves policy implementation efficiency based on feedback from platforms and enterprises.

B. COLLABORATIVE AND INTERACTIVE RELATIONSHIPS AMONG MULTIPLE SUBJECTS

Platforms, enterprises, consumers, governments and other entities form a collaborative promotion force through col-

TABLE 1. Core Components of Low-Carbon Product Promotion Mechanism on E-Commerce Platforms

Dimensions	Sub-Dimensions	Specific Contents
Core Subjects	E-commerce Platforms	Channel building, resource integration, strategy execution, data support, trust establishment
	Low-Carbon Enterprises	Product R&D, quality control, green certification, information disclosure, cooperative promotion
	Consumers	Green consumption participation, feedback provision, concept dissemination
	Government	Standard formulation, policy incentives, supervision implementation, publicity and education
Strategy Tools	Price Incentives	Platform subsidies, coupons, green points exchange, tiered discounts, trade-in subsidies
	Information Disclosure	Green certification labels, carbon footprint data, environmental performance descriptions, third-party test reports
	Channel Optimization	Low-carbon product zones, search priority, personalized recommendation, cross-category combination display
	Social Communication Scene Marketing	KOL/KOC recommendation, user sharing incentives, community marketing, public welfare linkage Consumption scene construction, thematic activities, immersive experience (online/offline)
Supporting Environment	Policy Environment	Certification standards, carbon footprint accounting methods, government subsidies, tax incentives, supervision systems
	Technical Environment	Big data analytics, artificial intelligence, blockchain, Internet of Things (IoT)
	Social Environment	Green consumption culture, social recognition, environmental education, consumers' green cognition level

TABLE 2. Comparison of Low-Carbon Product Promotion Mechanisms Between Comprehensive and Vertical E-Commerce Platforms

Comparison Dimensions	Comprehensive E-Commerce Platforms (Tmall, JD)	Vertical E-Commerce Platforms (NetEase Yanxuan, Xiaohongshu)
Core Characteristics	Large traffic scale, rich categories, mature technology, wide user coverage	Clear user portraits, professional positioning, strong community operation capabilities
Subject Interaction	Cooperate with numerous enterprises (SKU > 20,000), close cooperation with government, extensive audience	Cooperate with high-quality enterprises, in-depth interaction with niche groups, close linkage with vertical KOLs
Strategy Combination	Price incentives + channel optimization + information disclosure, large-scale thematic activities	Social communication + scene marketing + information disclosure, precise community operations
Advantages	Strong resource integration ability, wide promotion coverage, rapid market penetration improvement	High promotion accuracy, strong user stickiness, high repurchase rate (average 41.8%), significant concept guidance effect
Disadvantages	Homogeneous strategies, insufficient precise matching, over-reliance on price subsidies	Limited traffic scale, narrow promotion coverage, weak policy resource integration ability
Typical Cases	Tmall "Green Choice" zone, JD "Low-Carbon Living Hall", joint government carbon footprint certification	NetEase Yanxuan green home scene packages, Xiaohongshu environmental KOL promotion, user community experience sharing

laborative governance, and their collaborative interaction logic is reflected in "goal consistency - clear rights and responsibilities - resource integration - benefit sharing". The common goal of all parties is to promote low-carbon products and achieve carbon reduction targets, clarify their respective rights and responsibilities (government regulations, platform construction channels, enterprise product supply, and consumer participation in purchasing), integrate policy resources, technological resources, data resources, and market resources, and ultimately achieve a win-win situation for all parties (government achieving carbon reduction targets, platform enhancing competitiveness and revenue, enterprise expanding market share, and consumers obtaining environmental protection and use value).

C. BENEFIT SHARING-RISK SHARING COORDINATION MECHANISM

To resolve conflicts of interest between enterprises' profit goals and government environmental goals, a three-dimensional coordination mechanism is established:

Carbon emission reduction benefit sharing: Platforms and enterprises share government carbon emission reduction subsidies (e.g., 80 yuan per ton of carbon emission reduction) in a 3:7 ratio, with enterprises investing part of the benefits into low-carbon technology R&D;

Policy subsidy sharing: The government provides a 30%

tax credit for enterprises' low-carbon R&D investment, and the platform offers a 50% subsidy for green certification fees to reduce enterprises' green transformation costs;

Long-term cooperation binding: The platform signs long-term cooperation agreements (≥ 3 years) with enterprises, providing 50% traffic tilt for low-carbon products to help enterprises expand market share and offset short-term profit losses.

The common goal of all parties is to promote low-carbon products and achieve carbon reduction targets, clarify their respective rights and responsibilities (government regulations, platform construction channels, enterprise product supply, and consumer participation in purchasing), integrate policy resources, technological resources, data resources, and market resources, and ultimately achieve a win-win situation for all parties (government achieving carbon reduction targets, platform enhancing competitiveness and revenue, enterprise expanding market share, and consumers obtaining environmental protection and use value) [22,23]."

D. PROMOTION PROCESS AND CORE OPERATING MECHANISM

E. PROMOTION PROCESS

The complete process of promoting low-carbon products on e-commerce platforms includes five stages, each stage is interrelated and dynamically cycled:

Phase 1: Promotion Implementation: The platform carries out promotion activities according to the promotion plan, including setting up a low-carbon product zone, advertising, distributing subsidies and coupons, conducting themed activities, KOL recommendations, precise recommendations, etc; Enterprises cooperate with the platform to provide product information, carry out product experience activities, and respond to consumer inquiries; The government provides support through publicity and education, policy subsidies, and other means. The core goal of this stage is to attract consumers' attention and stimulate their willingness to purchase [24].

Phase 2: Effect monitoring and feedback: The platform monitors the promotion effect through transaction data (sales volume, sales revenue, market penetration rate), user data (click-through rate, browsing time, repurchase rate, evaluation score), carbon reduction data (product carbon emissions, total carbon emissions), etc; Collect opinions from various parties through consumer surveys, corporate feedback, government evaluations, etc; Third party organizations conduct independent evaluations of promotion effectiveness [25].

F. CORE OPERATING MECHANISM

The core operating mechanism of the promotion mechanism includes incentive mechanism, trust mechanism, collaboration mechanism, and feedback mechanism. The four mechanisms work together to ensure the smooth operation of the promotion process and the continuous improvement of the promotion effect

Incentive mechanism: Through price subsidies, traffic tilt, point rewards, policy subsidies, tax incentives, and other methods, enterprises are incentivized to settle in and provide products, consumers purchase and share, and platforms carry out promotional activities to stimulate the enthusiasm of all parties involved. For example, the platform provides traffic incentives for low-carbon products to encourage companies to settle in; Consumers who purchase low-carbon products can earn green points, motivating them to continue their consumption; The government provides promotion subsidies to platforms to encourage them to increase their promotion efforts.

G. DIFFERENCES IN PROMOTION MECHANISMS OF DIFFERENT TYPES OF E-COMMERCE PLATFORMS

1) Characteristics of the Promotion Mechanism of Comprehensive E-commerce Platforms

The core features of integrated e-commerce platforms such as Tmall, JD.com, and Pinduoduo are large traffic, diverse categories, a large user base, and mature technology. Their promotion mechanisms have the characteristics of scale, comprehensiveness, and diversification:

Main interaction: Establishing cooperative relationships with a large number of low-carbon product enterprises, with a large number of SKUs of settled products (over 20000 low-carbon product SKUs on Tmall); The user base covers

all age groups and consumption levels, and the promotional activities have a wide audience; Closely cooperate with the government, participate in the formulation of industry standards, and build a comprehensive green certification system.

Advantages and disadvantages: The advantages lie in the large traffic scale, wide promotion coverage, strong resource integration ability, and the ability to quickly increase the market penetration rate of low-carbon products; The shortcomings lie in the serious homogenization of promotion strategies, insufficient precise matching of segmented consumer groups, excessive reliance on price subsidies by some platforms, and high promotion costs.

IV. CONSTRUCTION OF EVALUATION INDEX SYSTEM FOR THE PROMOTION EFFECT OF LOW-CARBON PRODUCTS ON E-COMMERCE PLATFORMS

A. CONSTRUCTION PRINCIPLES OF EVALUATION INDEX SYSTEM

Indicator data should be easy to obtain and can be collected through channels such as platform transaction data, enterprise statistical data, questionnaire survey data, government public data, third-party institution reports, etc., to avoid setting indicators that are difficult to quantify or data cannot be obtained, and ensure the smooth progress of evaluation work. For example, the degree of improvement in consumer green awareness can be calculated through questionnaire survey data, and market penetration rate can be calculated through platform transaction data statistics.

B. EVALUATION INDEX SYSTEM CONTENT

Based on the above principles, combined with relevant theories and practical experience, a low-carbon product promotion effect evaluation index system for e-commerce platforms is constructed, which includes 4 primary indicators, 12 secondary indicators, and 36 tertiary indicators.

C. DETERMINATION AND EVALUATION METHOD OF INDICATOR WEIGHTS

1) Determination of Indicator Weights

The combination weighting method combining Analytic Hierarchy Process (AHP) and Entropy Weight Method is used to determine the weights of indicators, taking into account the dual advantages of subjective experience and objective data

1. Subjective weight determination (AHP method): Invite 20 experts (including e-commerce platform operation experts, low-carbon economy research scholars, government officials, enterprise marketing experts, and technical personnel from third-party certification agencies) to form an expert team, construct a judgment matrix, and score the relative importance of each indicator. Ensure the rationality of the judgment matrix through consistency testing ($CR < 0.1$) and calculate the subjective weights of each indicator.

2. Objective weight determination (entropy weight method): Based on collected empirical data (platform trans-

action data, enterprise data, questionnaire survey data, etc.), calculate the information entropy of each indicator. The smaller the information entropy, the greater the degree of dispersion of the indicator data, the higher the information value contained, and the greater the weight; Conversely, the smaller the weight. Calculate the objective weights of each indicator based on information entropy. The evaluation index system for the promotion effect of low-carbon products on e-commerce platforms is shown in Table 3:

V. EMPIRICAL ANALYSIS OF THE EFFECTIVENESS OF LOW-CARBON PRODUCT PROMOTION MECHANISM ON E-COMMERCE PLATFORMS

A. DESCRIPTIVE STATISTICAL ANALYSIS

In terms of promotion strategies, price incentives are the most commonly used promotion strategy on various platforms (with a usage rate of 92%), followed by information disclosure (85%) and channel optimization (78%). The usage rates of social communication and scenario marketing are higher on vertical e-commerce platforms (83% and 79% respectively, and 67% and 62% respectively for comprehensive e-commerce). The average score (1-5 points) of each promotion strategy is: information disclosure (3.8 points)>social communication (3.6 points)>channel optimization (3.5 points)>scenario marketing (3.3 points)>price incentives (3.2 points), indicating that consumers have a higher recognition of information disclosure and social communication strategies.

In terms of the degree of subject collaboration, the average score for platform enterprise cooperation closeness is 3.4 points, the average score for consumer participation enthusiasm is 3.2 points, and the average score for government support is 3.1 points. The overall level of collaboration is above average, but there is still room for improvement.

In terms of policy environment support, the average score for the completeness of certification standards is 2.9 points, the average score for policy subsidy intensity is 3.0 points, and the average score for the soundness of regulatory systems is 3.2 points, indicating that incomplete certification standards are the main weakness of the policy environment.

In terms of product types, the promotion effect of low-carbon products in the electronics and appliances category scored the highest (75.6 points), followed by home building materials category (72.3 points), food and fresh products category (69.8 points), and clothing and apparel category (67.5 points); In terms of price range, the promotion effect of low-carbon products in the mid-price range (500-2000 yuan) is the best (74.2 points), followed by low-price products (70.5 points), and high-price products are the worst (65.8 points); In terms of consumer characteristics, consumers aged 25-45, with a bachelor's degree or above, and a monthly income of over 5000 yuan have a higher willingness and participation in purchasing low-carbon products.

B. CORRELATION ANALYSIS

Pearson correlation analysis was used to test the correlation between variables, and the results showed that: The dimensions of promotion strategy (price incentives, information disclosure, channel optimization, social communication, and scenario marketing) are significantly positively correlated with promotion effectiveness ($p<0.01$), with information disclosure ($r=0.78$) having the highest correlation coefficient with social communication ($r=0.75$) and price incentives ($r=0.52$) having a relatively low correlation coefficient. There is a significant positive correlation ($r=0.72$, $r=0.68$, $r=0.65$, $p<0.01$) between the various dimensions of subject collaboration (platform enterprise cooperation closeness, consumer participation enthusiasm, government support) and promotion effectiveness.

There is a significant positive correlation ($r=0.63$, $r=0.58$, $r=0.61$, $p<0.01$) between the policy environment support dimensions (certification standard completeness, policy subsidy intensity, regulatory system soundness) and the promotion effect.

In the controlled variables, there is a weak correlation ($r<0.15$) between product type, price range, consumer age, education, income, and promotion effectiveness, indicating that the effect of the promotion mechanism is relatively stable and less affected by the controlled variables.

C. ANALYSIS OF DOUBLE DIFFERENCE MODEL

Taking the application of carbon footprint tracing technology as a policy shock, Tmall and JD.com (the treatment group that applies this technology) and Pinduoduo, NetEase Yanxuan, and Xiaohongshu (the control group that does not apply this technology) were selected as samples to evaluate the net effect of the policy using a difference in differences model. The results show that:

The coefficient of the double difference sub item ($T_i \times D_t$) is 0.15 ($p<0.01$), indicating that the application of carbon footprint tracing technology can significantly improve the comprehensive score of promotion effect by 15%, and the net effect of policy is significantly positive.

Further analysis of the effects in various dimensions shows that the application of carbon footprint tracing technology has the most significant improvement in environmental effects (net effect 0.21, $p<0.001$), followed by social effects (net effect 0.17, $p<0.01$), mechanism operation effects (net effect 0.14, $p<0.01$), and economic effects (net effect 0.10, $p<0.05$), indicating that this technology can comprehensively enhance the promotion effect, especially in the environmental and social dimensions.

D. CASE VALIDATION: PROMOTION PRACTICES AND EFFECTS OF TYPICAL PLATFORMS

A enterprise experienced a 15% cost increase due to low-carbon fabric R&D in the initial stage. Through platform traffic tilt (monthly sales increased by 80%), government tax credit (annual tax reduction of 2 million yuan), and carbon emission reduction subsidies (annual subsidy of 1.5 million

TABLE 3. Evaluation Index System for Low-Carbon Product Promotion Effect on E-Commerce Platforms

First-Level Indicators	Second-Level Indicators	Third-Level Indicators	Data Source	Weight Determination Method
Economic Effect (A)	Product Sales Performance (A1)	Sales volume, sales growth rate, market penetration rate, sales proportion	Platform transaction data	AHP + Entropy Weight Method
	Enterprise Benefit Level (A2)	Sales growth rate of settled enterprises, profit margin, market share increase	Enterprise survey data	AHP + Entropy Weight Method
	Platform Operation Benefit (A3)	Transaction volume, user activity, repurchase rate, promotion cost-benefit ratio	Platform operation data	AHP + Entropy Weight Method
Environmental Effect (B)	Carbon Reduction Benefit (B1)	Unit carbon emission reduction, total carbon reduction, carbon footprint optimization	Carbon accounting reports	AHP + Entropy Weight Method
	Resource Utilization Efficiency (B2)	Packaging recycling rate, logistics energy consumption reduction, water saving volume	Enterprise/platform data	AHP + Entropy Weight Method
	Pollution Reduction Effect (B3)	Pollutant emission reduction, environmental material usage ratio	Enterprise environmental reports	AHP + Entropy Weight Method
Social Effect (C)	Consumption Concept Guidance (C1)	Green cognition improvement, low-carbon behavior formation rate, environmental awareness enhancement	Questionnaire data	AHP + Entropy Weight Method
	Industry Demonstration Effect (C2)	Peer imitation rate, industry green transformation speed, standard formulation participation	Industry statistics	AHP + Entropy Weight Method
	Policy Response Effect (C3)	Policy goal achievement, government satisfaction, policy implementation efficiency	Government survey data	AHP + Entropy Weight Method
Mechanism Operation Effect (D)	Subject Synergy Degree (D1)	Platform-enterprise cooperation tightness, consumer participation, government support	Multi-party survey data	AHP + Entropy Weight Method
	Strategy Implementation Efficiency (D2)	Promotion cost-benefit ratio, strategy adjustment timeliness, resource allocation rationality	Platform data	AHP + Entropy Weight Method
	Sustainability Level (D3)	Mechanism stability, long-term promotion willingness, innovation capability	Multi-party survey data	AHP + Entropy Weight Method

yuan), it achieved profitability after 6 months. According to questionnaire survey data, 82% of the surveyed enterprises stated that "policy subsidies + traffic support" can effectively balance green costs and short-term profits.

1) Tmall: Scale based Collaborative Promotion Model of Comprehensive E-commerce Platform

Tmall promotes low-carbon products through a combination of policy cooperation, platform empowerment, and ecological construction. Its core promotion mechanism includes:

Main body collaboration: Cooperate with the government to establish a unified carbon footprint accounting standard and receive a subsidy of 80 yuan per ton of carbon reduction from the government; Signed cooperation agreements with over 2000 low-carbon product companies, providing traffic tilt and data support; Collect feedback through consumer communities and optimize promotion strategies.

Technological Empowerment: Utilizing big data to achieve precise recommendations and adopting blockchain technology to trace carbon footprints.

2) NetEase Strict Selection: Precise Community Promotion Model for Vertical E-commerce Platforms

NetEase Yanxuan focuses on the positioning of "quality life+green environmental protection" and adopts a promotion model of "boutique screening+scene marketing+community operation". Its core promotion mechanism includes:

Strategy combination: Select high-quality low-carbon products to settle in (channel optimization), create "green home" and "low-carbon travel" scenario packages (scenario marketing), invite environmental experts to share experiences (social communication), and publicly release product environmental performance testing reports (information disclosure).

Technical empowerment: Based on user profiles, achieve accurate recommendations and optimize product and promotion strategies through community data.

Data shows that NetEase's strict selection of low-carbon products has a repurchase rate of 41.8% (10 percentage

points higher than the industry average), a 65% improvement in consumer green awareness, and a comprehensive promotion effect score of 72.3 points (good level), forming a good demonstration effect in the vertical field and verifying the effectiveness of the precision community promotion mechanism.

E. EXPLANATION OF REPURCHASE RATE DATA

Data source: Platform backend transaction database;

Extraction logic: Calculate the proportion of users who purchased low-carbon products of the same category again within 6 months from January to December 2023;

Extraction steps:

① Screen product orders with keyword tags of "low-carbon certification" and "green environmental protection";

② Match user IDs to eliminate duplicate orders and malicious brushing orders (according to platform risk control rules);

③ Calculate the ratio of repeat purchase users to total purchase users;

Statistical scope: Two core low-carbon product categories, involving 126,000 users and 382,000 orders;

Third-party verification: This data has been verified by iResearch and is basically consistent with the average repurchase rate of low-carbon products in vertical e-commerce (40.2%) in the "2024 China Green Consumption Market Research Report". The net effect of carbon footprint tracking technology on the promotion effect is shown in Table 4:

VI. OPTIMIZATION MEASURES FOR THE PROMOTION MECHANISM OF LOW-CARBON PRODUCTS ON E-COMMERCE PLATFORMS UNDER THE GUIDANCE OF GREEN CONSUMPTION

Based on empirical analysis results and case studies, combined with the operational logic and practical difficulties of the promotion mechanism, this paper proposes an optimization path and specific countermeasures for the promotion mechanism, which includes "precise strategy, deep collaboration, environmental adaptation, and technological empowerment".

TABLE 4. Net Effect of Carbon Footprint Tracking Technology on Promotion Effect (DID Model Results)

Effect Dimensions	Treatment Group (Tmall/JD)	Control Group (Pinduoduo/NetEase Yanxuan/Xiaohongshu)	Net Effect (Coefficient)	Significance Level
Comprehensive Promotion Effect	78.5/76.3	69.8/72.3/68.5	0.15	p < 0.01
Economic Effect	79.2/77.8	70.5/73.2/69.1	0.10	p < 0.05
Environmental Effect	77.5/76.9	68.3/71.5/67.8	0.21	p < 0.001
Social Effect	73.2/72.5	69.5/76.8/74.5	0.17	p < 0.01
Mechanism Operation Effect	75.6/74.8	68.9/73.6/72.4	0.14	p < 0.01

A. STRATEGY PRECISION: OPTIMIZE THE COMBINATION OF PROMOTION STRATEGIES TO ENHANCE ACCURACY AND EFFECTIVENESS

Build a multi-level price incentive system of "subsidies+points+discounts+public welfare" to avoid excessive reliance on direct subsidies:

Precise subsidies: increase subsidies for low - and mid-price low-carbon products, emerging low-carbon products, and lower the entry threshold for consumers; Implement tiered discounts for high-value low-carbon products, encourage bulk purchases and long-term use; Provide targeted subsidies for groups with strong green consumption willingness but limited payment ability, such as students and low-income groups.

Green points system: Consumers who purchase low-carbon products, share environmental experiences, and participate in environmental activities can accumulate green points, which can be exchanged for low-carbon products, environmental protection peripherals, or deducted in cash; Points can be linked to carbon emissions reduction, and consumers can donate their points to environmental public welfare projects to enhance their sense of social value in consumption.

If consumers choose to exchange for peripheral products, they are limited to "environmentally friendly products made of biodegradable materials (such as bamboo tableware, cotton cloth bags)", with an exchange limit of 3 pieces per person per year. At the same time, suppliers are required to provide product carbon footprint reports (ensuring that the carbon emissions of peripheral products are $\leq 5\text{kgCO}_2\text{eq/piece}$) to avoid unnecessary consumption for environmental protection.

The core design of the points mechanism is to "encourage repeat purchases of low-carbon products + reduce unnecessary consumption". By setting the weight of exchange options (low-carbon product deduction ratio $\geq 70\%$), consumers are guided to focus on low-carbon consumption itself rather than simply obtaining peripheral products, eliminating the controversy of "greenwashing".

Public welfare linkage: Cooperate with environmental protection public welfare organizations to donate some of the promotion proceeds to carbon reduction projects. Consumers who purchase low-carbon products can receive public welfare donation certificates, enhancing the sense of meaning of consumption.

B. DEEPENING COLLABORATION: STRENGTHEN THE COLLABORATION AND LINKAGE OF THE MAIN BODY, AND BUILD A MULTI-PARTY WIN-WIN PROMOTION ECOSYSTEM

1) Deepen the Deep Cooperation Between the Platform and Enterprises

Establish strategic partnership: The platform signs long-term cooperation agreements with high-quality low-carbon product enterprises, clarifying the rights and responsibilities of both parties and the distribution ratio of benefits; The platform provides "one-stop services" for enterprises, including green certification subsidies, entry into green channels, data support, product design consulting, etc., to reduce the cost of enterprise entry and promotion.

Joint product development and promotion: The platform provides demand insights for enterprises based on consumer behavior data, helping them optimize low-carbon product design (such as improving environmental performance and reducing prices); Enterprises and platforms jointly carry out promotional activities such as new product launches and themed promotions, sharing costs and benefits; The platform provides incentives such as traffic tilt and priority recommendation to enterprises with good promotion effects and excellent product quality.

C. ENHANCE CONSUMER ENGAGEMENT AND TRUST

Strengthen green consumption education: Through platform homepage pop ups, special articles, short videos, environmental knowledge Q&A and other forms, popularize low-carbon consumption knowledge, carbon footprint concepts, environmental policies, etc., and enhance consumers' green awareness; In response to the "knowledge-action gap" among consumers, through case studies and visual effects, we aim to provide consumers with a clear understanding of the environmental and practical value of low-carbon products.

1) Strengthen Policy Coordination Between The Platform and the Government

Strive for policy resource support: Proactively apply to the government for policy support such as promotion subsidies, tax incentives, carbon reduction rewards, etc., to make policy dividends beneficial to consumers and enterprises, and reduce promotion costs; Utilize government propaganda channels (such as government websites and official media) to carry out joint promotion and expand influence.

D. BUILDING A MULTI SUBJECT COLLABORATIVE GOVERNANCE PLATFORM

Establish a multi-party collaborative governance platform composed of platforms, enterprises, consumers, governments, industry associations, and third-party organizations to achieve information sharing, resource integration, and interest coordination

Information sharing mechanism: Through collaborative platforms, policy information, certification standards, product information, consumer feedback, carbon reduction data, etc. are shared to reduce information asymmetry.

Resource integration mechanism: Integrate policy resources, technical resources, data resources, and market resources to jointly carry out low-carbon product research and development, promotion activities, environmental protection publicity, etc.

Interest coordination mechanism: Clarify the interests and responsibilities of all parties involved, establish a benefit sharing mechanism (such as carbon emission reduction revenue sharing), resolve conflicts of interest, and achieve win-win outcomes.

Supervision and evaluation mechanism: Independent evaluation of the effectiveness of the promotion mechanism by third-party organizations, publication of evaluation reports, acceptance of social supervision, and promotion of continuous optimization of the promotion mechanism.

VII. CONCLUSION

Integrating the Theory of Planned Behavior, the Technology Acceptance Model, and Collaborative Governance Theory, this article constructs a "Subject-Strategy-Environment-Effect" analytical framework to evaluate the green transition and low-carbon technological adoption within the industry. Through empirical research and typical case analysis using multiple methods, the core connotation, operational logic, and practical effects of the low-carbon product promotion mechanism of e-commerce platforms under the guidance of green consumption are systematically analyzed. Finally, the following core conclusions are formed:

The three-dimensional composition system and interactive logic of the promotion mechanism have been clarified. The promotion mechanism consists of core entities (e-commerce platforms, low-carbon product enterprises, consumers, and governments), five strategic tools (price incentives, information disclosure, channel optimization, social communication, and scenario marketing), and three supporting environments (policy environment, technology environment, and social environment). Each element forms an organic whole through the interactive relationship of "resource complementarity demand matching policy guidance". Among them, the "win-win cooperation" between the platform and enterprises, the "service feedback" between the platform and consumers, and the "policy response" interaction between the government and multiple parties jointly constitute the core driving force for the operation of the promotion mechanism. Revealed the differences and adapt-

ability of promotion mechanisms among different types of e-commerce platforms. Integrated e-commerce platforms (Tmall, JD) leverage their advantages in traffic scale and resource integration to form a "scale based collaborative promotion" model, adept at rapidly increasing market penetration through price incentives and channel optimization; Vertical e-commerce platforms (NetEase Yanxuan, Xiaohongshu) rely on precise user profiles and community operation capabilities to build a "precise community promotion" model, achieving high user stickiness and repeat purchase rates (with an average repeat purchase rate of 41.8%) through social communication and scene marketing. Each model has its own advantages and disadvantages, and is suitable for different promotion goals and product types.

AUTHOR CONTRIBUTIONS

Qianwen Lv designed, collected and analyzed the data, and drafted the manuscript. Qianwen Lv conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Qianwen Lv participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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