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The Implementation Strategy of Low-Carbon Supply Chain for Cross-Border E-Commerce under "Carbon Tariffs"

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Abstract

In response to increasingly severe climate change challenges, the international community has gradually reached a consensus on carbon emission reduction, fostering the development of green trade barriers such as carbon tariffs, which exert profound impacts on import and export trade. As a new driving force in foreign trade, cross-border e-commerce must confront the challenges posed by green barriers, establish and implement low-carbon supply chains, and enhance market competitiveness. To identify the optimal strategies for implementing low-carbon supply chains in cross-border e-commerce, this paper establishes a tripartite game model involving governments, enterprises, and consumers. Through analyzing the mixed strategy equilibrium, it is demonstrated that general regulation through fiscal incentives and tax surcharges fails to enhance the effectiveness of macroeconomic control. When formulating strategies, governments should prioritize the sustainable development of low-carbon supply chains in cross-border e-commerce, improve incentive mechanisms by adopting "green regulation" strategies with special subsidies, and prioritize developing low-carbon technologies and supporting facilities, as well as promoting carbon trading mechanisms.

Keywords

Cross-Border E-Commerce, Low-Carbon Supply Chain, Carbon Tariff, Tri-Party Game, Optimal Strategy

1. Introduction

The global climate change problem has become increasingly severe. Excessive greenhouse gas emissions have led to global temperature rise, sea level rise, and frequent extreme climate events, severely threatening human survival and development. To combat climate change, the international community has reached a consensus on carbon emission reduction and signed the Paris Agreement.

As one of the world's largest carbon emitters, China has proactively taken on the responsibility of addressing climate change. It has set the ambitious goals of achieving carbon peak by 2030 and carbon neutrality by 2060. These goals are intrinsic to China's comprehensive green transformation and high-quality development. To achieve these targets, China has implemented the "1 + N" policy framework and outlined a timeline and roadmap in the "Action Plan for Carbon Peak Before 2030".

The EU has proposed the Carbon Border Adjustment Mechanism (CBAM), also known as carbon tariffs, with a transition period before 2025. Recent studies highlight the asymmetric impacts of carbon tariffs on developing economies, emphasizing the need for equitable policy frameworks (Gu et al., 2023; Dai & Xiang, 2023). This mechanism will be fully implemented gradually from 2026 to 2034. Under the new regulations, the EU will impose additional taxes on imports of steel, aluminum, cement, and fertilizers. EU importers must now report greenhouse gas emissions from the production process of these goods. Starting January 1, 2026, importers must purchase emission certificates priced based on the carbon price for producing these goods within the EU.

Following the EU's lead, the UK has announced the implementation of its own Carbon Border Adjustment Mechanism starting in 2027, initially covering product categories such as aluminum, cement, ceramics, fertilizers, glass, hydrogen, and steel. The US and Australia are also considering introducing similar mechanisms. The implementation of CBAM is set to trigger a significant reshuffle of the global industrial landscape and market shares.

Foreign trade is crucial to China's open-economy and national economic growth. The Central Economic Work Conference highlighted the importance of fostering new foreign-trade drivers, proposing measures such as strengthening foreign-trade and foreign-investment infrastructure and expanding trade in intermediate products, services, digital products, and cross-border e-commerce. In recent years, e-commerce, especially cross-border e-commerce, has grown rapidly in China, becoming a foreign-trade highlight. According to Chinese customs, China's cross-border e-commerce import and export volume reached 2.38 trillion yuan in 2023, up 15.6%. Cross-border e-commerce, as a strategic new trade route, not only effectively stimulates the potential of domestic supply chains and releases production capacity but also continuously enhances China's synergy in integrating domestic and international markets and resources (Wang et al., 2024). Promoting the integration of domestic and foreign trade helps achieve the "dual-circulation" pattern of focusing on domestic circulation while promoting mutual growth between domestic and international circulations. Promoting the convergence of domestic and foreign trade aligns with the "dual-circulation" strategy, which prioritizes domestic economic cycles while fostering symbiotic growth between national and global markets.

To cope with green trade barriers, it is essential to accelerate the construction of a green trade system, improve supporting policies, strengthen green low-carbon technology innovation, expedite certifications of green low-carbon products, and develop green low-carbon supply chains (Liu, 2024). Low-carbon supply chains cover a product's entire life cycle, from design through production, sales, consumption, and recycling, and are both prerequisites for cross-border e-commerce and emerging trends in the logistics industry (Chen & Yang, 2023). Therefore, researching strategies for implementing low-carbon supply chains in cross-border e-commerce under carbon tariffs is highly necessary.

2. Theoretical Research and Literature Review

Broadly speaking, carrying out sustainable supply chain practices in cross-border e-commerce isn't a single firm's action, but a joint task for all stakeholders. Apart from the leading company, consumers, government agencies, supply chain partners, and competitors all play crucial roles in this process.

1) The Organizer—Government

The government, as the policymaker, social manager, supervisor of businesses and consumers, and arbitrator of conflicts, has the power and duty to promote the development of cross-border e-commerce low-carbon supply chains and regulate irrational behaviors within them, acting as an organizational manager (Yang et al., 2024). Its main goal in participating is to represent public interests, ensure rational resource use, and promote sustainable socio-economic development. Unlike individual consumers, the government can directly decide on the redistribution of interests among businesses and exert strong influence over them.

2) The Implementer—Enterprise

Businesses are the direct implementers of cross-border e-commerce low-carbon supply chains. To enhance product greenness, expand market share, and strengthen the competitiveness of low-carbon products, an increasing number of enterprises are investing in green technology and product development to cut carbon emissions in production and supply chain operations, which requires significant human, material, and financial resources (Pan et al., 2023). Thus, when making low-carbon supply chain strategy decisions, cross-border e-commerce companies must consider various factors. In information-asymmetric situations, companies facing consumers' diverse rational choices must also consider competitors' actions and intercompany interest coordination issues. Moreover, the implementation of low-carbon supply chains by cross-border e-commerce companies is directly influenced by government regulation. Companies may act differently depending on the level of regulation or subsidies, and the government often tailors policies to companies' behaviors, creating an interactive relationship.

3) The Promoter—Consumer

Consumers engage in cross-border e-commerce low-carbon supply chain decision-making mainly to obtain product or service value equivalent to the utility of the money they spend. However, information asymmetries between consumers, enterprises, and governments—such as incomplete knowledge about the true environmental impact of products—can distort purchasing decisions and hinder the adoption of low-carbon practices (Huang & Zhou, 2024). They have personal preferences for product price and greenness when making choices. As environmental awareness grows, consumers' environmental consciousness influences their thinking and purchasing intentions (Huang & Zhou, 2024). Generally, green low-carbon products, though environmentally friendly, are often more expensive. While they attract consumers sensitive to green issues, they may deter price-sensitive ones due to high costs (Xie & Guan, 2024).

In summary, the production of green products and the implementation of low-carbon supply chains are influenced by the government, enterprises, and consumers. It is necessary to analyze the strategy choices and evolution paths among these three entities (Wang, 2023). Yang et al. (2023) developed a carbon-reduction decision model for supply-chain enterprises using a non-cooperative-cooperative game framework, investigating strategy choices and benefit-allocation issues under government regulation and growing low-carbon product demand. Zhang and Zhang (2024) established a three-stage Stackelberg game model and a centralized decision-making model for a three-tier low-carbon supply chain, considering government carbon-trading regulation and green subsidy policies. However, these studies did not account for consumer-centered utility. Deng (2023) created a closed-loop supply chain with a manufacturer, retailer, and consumer, analyzing strategy choices in a low-carbon supply chain via evolutionary game. Han et al. (2023) developed a dual-channel green supply-chain model with a manufacturer and retailer, considering consumer reference prices to study optimal pricing and product greenness decisions in traditional retail and online direct-sales channels. But these studies lacked analysis of government policy impacts. Zhang et al. (2023) constructed a game model among manufacturers, retailers, and consumers under carbon subsidy, carbon tax, and carbon trading policies, examining equilibrium conditions for different strategy combinations. Zhou & Fu (2024) studied pricing strategies for a dual-channel green supply chain with a manufacturer and retailer, considering government subsidies and consumer dual preferences. Although these studies considered government and consumer impacts, they mainly focused on pricing strategies between manufacturers and retailers, without analyzing the government and consumers as implementation entities for low-carbon supply chains.

This paper applies game theory to build a mixed-strategy model involving the government, enterprises, and consumers. It analyzes the behavioral characteristics of the entities involved in the implementation of low-carbon supply chains in cross-border e-commerce and aims to identify optimal implementation strategies under the three-party game.

3. Problem Description and Model Building

When market mechanisms fail to regulate effectively, the government should use administrative or economic means to oversee and incentivize enterprises and consumers. With the development of information technology, the market is no longer a complete "black box". Consumers can learn about corporate behavior patterns through various channels. Therefore, the decision-making problem of implementing a low-carbon supply chain in cross-border e-commerce is a mixed game among the three parties. To analyze the behavioral characteristics of the entities involved in the implementation of low-carbon supply chains in cross-border e-commerce, this study develops a tripartite game model consisting the government, enterprises, and consumers, aiming to find optimal strategies.

3.1. Model Assumptions and Parameter Settings

To grasp the research question's essence, simplify complex issues, and mirror real-life behaviors, the following assumptions are made for the game model:

1) Rational Economic Agents: All players (government, enterprises, consumers) act to maximize their own interests, with the government seeking maximum social welfare.

2) Perfect Information Dynamic Game: All parties have full information about each other's strategies and payoffs through IT.

3) Sequential Game Order: The game proceeds in the order of government, enterprise, and consumer. The government sets policies, enterprises decide on low-carbon supply chain strategies, and consumers make purchasing decisions.

4) Simplified Cost and Profit: The model focuses only on the costs and benefits related to implementing low-carbon supply chains, setting other costs and profits to zero to highlight key factors.

To support the development of low-carbon supply chains in cross-border e-commerce, the government can provide special funds to help enterprises implement low-carbon supply chains, reduce their implementation costs, enhance carbon trading systems, and subsidize products purchased through low-carbon supply chains. This lowers consumers' purchase costs. The government can also use fiscal and tax measures, such as tax breaks for enterprises adopting low-carbon supply chains and taxes on products from traditional supply chains, to narrow the cost gap between the two.

In this model, the government's two strategies are named green regulation a_{g1} and general regulation a_{g2}, with proportion p_g and $1-p_g$, forming the government's strategy space $A_g = \{a_{g1}, a_{g2}\}$. Enterprises can choose low-carbon supply chain a_{m1} or traditional supply chain a_{m2}, with proportion p_m and $1-p_m$, making the enterprise's strategy space $A_m = \{a_{m1}, a_{m2}\}$. Consumers can purchase through low-carbon a_{c1} or traditional a_{c2} supply chains, with proportion p_c and $1-p_c$, giving the consumer's strategy space $A_c = \{a_{c1}, a_{c2}\}$. The game tree below illustrates the game process among the government (G), enterprise (M), and consumer (C) (**Figure 1**).

Other parameter settings for the above model are shown in **Table 1**.

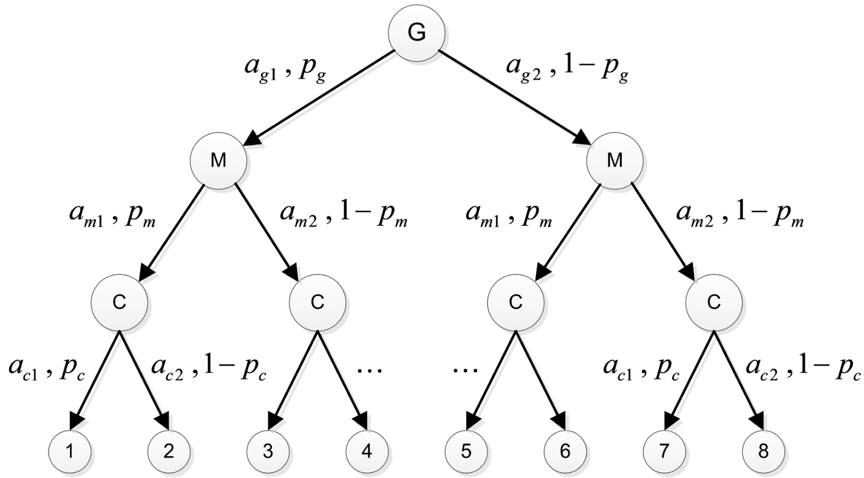

Figure 1. The tripartite game tree of government, enterprises, and consumers in the low-carbon supply chain of cross-border e-commerce.

Table 1. Parameter settings of the tripartite game model.

Parameter	Description
T	The government's effective investment when choosing the green regulation strategy. For example, subsidies for enterprises' low-carbon technology R&D and carbon trading promotion, and subsidies for consumers buying products via low-carbon supply chains. The value of T is equivalent to the extra benefits enterprises and consumers gain from the successful implementation of a low-carbon supply chain in cross-border e-commerce.
β	The proportion of benefits enterprises get from the government's effective investment. Under the government's green regulation strategy, enterprises' extra benefits are βT, and consumers' extra benefits are $(1-\beta)T$.
W	The social welfare the government gains from promoting the development of low-carbon supply chains in cross-border e-commerce, such as increased imports and exports.
B	The additional benefits from implementing a low-carbon supply chain, such as tax breaks and subsidies. To stress the government's long-term green strategy, assume $B > T$.
F	The loss consumers face when buying products through high-carbon channels, like carbon taxes.
R_i	Enterprise revenue: Assume enterprises gain R_1 from low-carbon supply chains and R_2 from traditional ones.
C_i	Enterprise costs: Assume total costs for low-carbon supply chains are C_1, and for traditional ones, C_2. Since low-carbon supply chains need advanced technology and more resources, $C_1 > C_2$.
U_i	Consumer utility: Assume utility from low-carbon supply chains is U_1, and from traditional ones, U_2. Given growing environmental awareness and advocacy for green consumption, low-carbon products offer a healthier, eco-friendly lifestyle, so $U_1 > U_2$.

3.2. Payoff Matrix and Strategy Combinations

Based on the tripartite game tree model, the payoff matrices for the government, enterprises, and consumers are presented in Table 2.

Table 2. Payoff matrices of government, enterprises, and consumers.

j	a_{ij} Strategy combinations	Payoff		
		$u_g(a_{gj})$	$u_m(a_{mj})$	$u_c(a_{cj})$
1	(a_{g1}, a_{m1}, a_{c1})	$W-T$	$R_1-C_1+\beta T$	$U_1+(1-\beta)T$
2	(a_{g1}, a_{m1}, a_{c2})	$-T$	$-C_1+\beta T$	0
3	(a_{g1}, a_{m2}, a_{c1})	$-T$	$-C_2$	0
4	(a_{g1}, a_{m2}, a_{c2})	$-T$	R_2-C_2	U_2
5	(a_{g2}, a_{m1}, a_{c1})	$W-B$	R_1-C_1+B	U_1
6	(a_{g2}, a_{m1}, a_{c2})	$-B$	$-C_1+B$	0
7	(a_{g2}, a_{m2}, a_{c1})	0	$-C_2$	0
8	(a_{g2}, a_{m2}, a_{c2})	F	R_2-C_2	U_2-F

Note: $u_g(a_{gj})$, $u_m(a_{mj})$, and $u_c(a_{cj})$ represent the payoff functions for the government, enterprises, and consumers, respectively, under different action combinations.

As shown in Table 2, the payoff functions for each party under different strategies are presented in Table 3.

Table 3. Payoff functions of government, enterprises, and consumers under different strategies.

Strategic party	Strategies	Payoff functions
Government	Green regulation strategy (a_{g1})	$u_{g1} = p_m p_c u_g(a_1) + p_m(1-p_c)u_g(a_2) + (1-p_m)p_c u_g(a_3) + (1-p_m)(1-p_c)u_g(a_4) = p_m p_c(W-T) + p_m(1-p_c)(-T) + (1-p_m)p_c(-T) + (1-p_m)(1-p_c)(-T)$
	General regulation strategy (a_{g2})	$u_{g2} = p_m p_c u_g(a_5) + p_m(1-p_c)u_g(a_6) + (1-p_m)p_c u_g(a_7) + (1-p_m)(1-p_c)u_g(a_8) = p_m p_c(W-B) + (1-p_m)p_c(-B) + (1-p_m)(1-p_c)F$
Enterprises	Low-carbon supply chains (a_{m1})	$u_{m1} = p_g p_c u_m(a_1) + p_g(1-p_c)u_m(a_2) + (1-p_g)p_c u_m(a_5) + (1-p_g)(1-p_c)u_m(a_6) = p_g p_c(R_1-C_1+\beta T) + p_g(1-p_c)(-C_1+\beta T) + (1-p_g)p_c(R_1-C_1+B) + (1-p_g)(1-p_c)(-C_1+B)$
	Traditional supply chains (a_{m2})	$u_{m2} = p_g p_c u_m(a_3) + p_g(1-p_c)u_m(a_4) + (1-p_g)p_c u_m(a_7) + (1-p_g)(1-p_c)u_m(a_8) = p_g p_c(-C_2) + p_g(1-p_c)(R_2-C_2) + (1-p_g)p_c(-C_2) + (1-p_g)(1-p_c)(R_2-C_2)$

Continued

Consumers	Purchase from low-carbon supply chain channels (a_{c1})	$u_{c1}=p_g p_m u_c(a_1)+p_g(1-p_m)u_c(a_3)$ $+(1-p_g)p_m u_c(a_5)+(1-p_g)(1-p_m)u_c(a_7)$ $=p_g p_m(U_1+(1-\beta)T)+(1-p_g)p_m U_1$
	Purchase from traditional supply chain channels (a_{c2})	$u_{c2}=p_g p_m u_c(a_2)+p_g(1-p_m)u_c(a_4)$ $+(1-p_g)p_m u_c(a_6)+(1-p_g)(1-p_m)u_c(a_8)$ $=p_g(1-p_m)U_2+(1-p_g)(1-p_m)(U_2-F)$

When the expected payoffs of all strategies are equal, a mixed-strategy Nash equilibrium is achieved, as players' payoffs become strategy-invariant. Specifically, when $u_{g1}=u_{g2}$, $u_{m1}=u_{m2}$, and $u_{c1}=u_{c2}$, the mixed-strategy Nash equilibrium for the government, enterprises, and consumers in the low-carbon supply chain implementation game of cross-border e-commerce can be derived as follows:

$$\begin{cases} p_g^*=\dfrac{B+p_c R_1-(1-p_c)R_2-(C_1-C_2)}{B-\beta T} \\ p_m^*=\dfrac{U_2-(1-p_g)F}{U_1+U_2+(1-\beta)p_g T-(1-p_g)F} \\ p_c^*=\dfrac{T+(1-p_m)F-p_m B}{(1-p_m)F} \\ p_g^*,\ p_m^*,\ p_c^*\in[0,1] \end{cases} \tag{1}$$

4. Model Solution and Analysis

4.1. Analysis of Consumers' Equilibrium Solutions

Differentiating p_c^* with respect to T in Equation (1) yields:

$$\frac{\partial p_c^*}{\partial T}=\frac{1}{(1-p_m)F} \tag{2}$$

Equation (2) indicates that p_c^* increases monotonically with T. Thus, the government's green regulation strategy a_{g1} encourages consumers to purchase via low-carbon supply chains, as the additional consumer benefits from increased government investment T raise the probability p_c^*.

Differentiating p_c^* with respect to B in Equation (1) yields:

$$\frac{\partial p_c^*}{\partial B}=\frac{-p_m}{(1-p_m)F} \tag{3}$$

Equation (3) shows that p_c^* decreases monotonically with B. Consequently, the government's general regulatory strategy a_{g2} based on fiscal incentives does not positively influence consumers. Instead, as tax breaks and benefits B for enterprises rise, consumers are more inclined to purchase through traditional supply channels.

Differentiating p_c^* with respect to F in equation (1) yields:

$$\frac{\partial p_c^*}{\partial F}=\frac{p_m B-T}{(1-p_m)F^2} \tag{4}$$

Equation (4) reveals no strict monotonic relationship between p_c^* and F. The impact of F on p_c^* largely hinges on the interplay between government's effective investment T under green regulation a_{g1} and the benefits B offered to enterprises under general regulation a_{g2}. If $p_m B-T>0$, p_c^* increases with F; if $p_m B-T<0$, p_c^* decreases with F. This suggests that with an imperfect incentive mechanism and insufficient government investment, increasing taxes on cross-border e-commerce products for consumers does not encourage them to switch to low-carbon supply chain channels.

In summary, the government can incentivize consumers to switch from traditional channels to cross-border e-commerce low-carbon supply chain channels by improving tax policies (such as setting reasonable tax breaks for enterprises) and increasing effective investment in low-carbon supply chains (such as developing low-carbon technologies, improving relevant infrastructure, promoting carbon trading and carbon credit mechanisms, and subsidizing price differentials caused by green barriers). Further analysis indicates that $\left|\partial p_c^*/\partial T\right|>\left|\partial p_c^*/\partial B\right|$, which demonstrates that T has a more powerful influence on consumers' choices.

4.2. Analysis of Enterprise's Equilibrium Solutions

Differentiating p_m^* with respect to F yields:

$$\frac{\partial p_m^*}{\partial F}=\frac{-\left(1-p_g\right)\left(U_1+\left(1-\beta\right)p_g T\right)}{\left(U_1+U_2+p_g T-\beta p_g T+p_g F-F\right)^2} \tag{5}$$

This indicates p_m^* is a decreasing function of F. Thus, the government's general regulatory strategy a_{g2} based on fiscal incentives does not positively impact enterprises. Instead, as the carbon tax F on cross-border e-commerce products increases, enterprises are more inclined to implement traditional supply chains.

Differentiating p_m^* with respect to T yields:

$$\frac{\partial p_m^*}{\partial T}=\frac{(1-\beta)\left(U_2+p_g F-F\right)}{\left(U_1+U_2+p_g T-\beta p_g T+p_g F-F\right)^2} \tag{6}$$

Since $U_2>F$ and $U_2+p_g F-F>0$, p_m^* is an increasing function of T. This means increasing the government's investment T in low-carbon supply chains under the green regulation strategy a_{g1} promotes enterprise adoption of low-carbon strategies a_{m1}.

Differentiating p_m^* with respect to β yields:

$$\frac{\partial p_m^*}{\partial \beta}=\frac{p_g T\left(U_2+p_g F-F\right)}{\left(U_1+U_2+p_g T-\beta p_g T+p_g F-F\right)^2} \tag{7}$$

This shows p_m^* is an increasing function of β. By raising the proportion β of enterprise profits from government investment, the government can boost the probability p_m^* of enterprises implementing the low-carbon supply chain strategy a_{m1}.

In conclusion, government measures to increase enterprise benefits from implementing low-carbon supply chains, such as investing in low-carbon technologies and carbon trading mechanisms, can strongly motivate enterprises to adopt low-carbon supply chains.

4.3. Analysis of Government's Equilibrium Solutions

Differentiating p_g^* with respect to T gives:

$$\frac{\partial p_g^*}{\partial T}=\frac{b\left(B-C_1+C_2+p_cR_1-R_2+p_cR_2\right)}{\left(B-\beta T\right)^2} \tag{8}$$

Since $p_g^*>0$, $B-\beta T>0$, $B-C_1+C_2+p_cR_1-R_2+p_cR_2>0$. This shows p_g^* is an increasing function of T. In other words, the more funds T the government allocates to low-carbon supply chains in cross-border e-commerce, the higher the probability p_g^* that it will adopt the green regulation strategy a_{g1}.

Differentiating p_g^* with respect to β gives:

$$\frac{\partial p_g^*}{\partial \beta}=\frac{\left(B-C_1+C_2+p_cR_1-R_2+p_cR_2\right)T}{\left(B-\beta T\right)^2} \tag{9}$$

This indicates p_g^* is an increasing function of β. Thus, raising the proportion β of enterprise profits from government investment promotes the adoption of the green regulation strategy a_{g1}.

In summary, similar to the enterprise equilibrium analysis, when the government increases investment in low-carbon supply chains, enterprises gain more benefits and are more motivated to implement low-carbon strategies. In turn, the government, aiming for greater social welfare, becomes more proactive in investing in R&D, construction, and promotion, thus advancing the development of low-carbon supply chains in cross-border e-commerce.

4.4. Limitations and Future Research Directions

This study focuses on cross-border e-commerce, and its findings may not generalize to other trade sectors (e.g., traditional manufacturing or service industries). Future work should extend the tripartite game model to broader supply chain contexts to enhance applicability.

5. Conclusions and Policy Recommendations

Implementing low-carbon supply chain strategies in cross-border e-commerce is a multi-party game. On the one hand, it is a typical prisoner's dilemma among enterprises. Initially, any enterprise's intention to implement a low-carbon supply chain may be abandoned due to the other parties' defection, leading to a Nash equilibrium where all choose not to implement it. On the other hand, the game between enterprises and consumers, marked by information asymmetry, leads enterprises to adopt traditional supply chain strategies to "free ride", leaving consumers with no incentive to encourage low-carbon supply chains. Thus, without government oversight and incentives, enterprises base their strategies on predicting competitors' moves, resulting in a Nash equilibrium that is the worst overall outcome, eliminating the possibility of all cross-border e-commerce firms implementing low-carbon supply chains. Hence, the government is a key factor influencing the development of low-carbon supply chains in cross-border e-commerce.

Based on the mixed-strategy equilibrium of the tripartite game model involving the government, enterprises, and consumers, the following policy recommendations are proposed to promote the implementation of low-carbon supply chains and enhance government regulatory effectiveness:

1) Establish and Improve Incentive Mechanisms

Increasing the discount B for enterprises implementing low-carbon supply chains and strengthening the regulation and taxation F on consumers purchasing through high-carbon supply chains do not actively enhance government regulatory efficiency. In fact, improper discounts can counteract the intended effects despite increased investment T.

2) Focus on Sustainable Industrial Development

General regulatory strategies centered on discounts B and taxes F can promote short-term growth in low-carbon supply chains but do not address market fundamentals and are unsustainable. Analysis of equilibrium solutions indicates that increasing the implementation probability p_m^* of enterprises and the usage probability p_c^* of consumers requires a shift in government focus to green regulation strategies. This includes supporting low-carbon technology R&D, improving infrastructure, and promoting carbon trading and carbon credit mechanisms.

3) Prioritize Low-Carbon Technology Development, Infrastructure Improvement, and Carbon Trading Mechanisms

With consistent government investment T, adjusting the profit-sharing ratio β between enterprises and consumers allows enterprises to gain more benefits, incentivizing low-carbon supply chain implementation. Compared to consumer subsidies, reducing enterprise costs through low-carbon technology development and increasing their revenue via carbon trading mechanisms are more effective in enhancing government regulatory efficiency.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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