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Unilateral, bilateral, or tariff-free: How tariff structures affect competing manufacturers in a cross-border supply chain?

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A B S T R A C T

To examine the impact of different tariff structures on cross-border supply chains and support multinational corporations in addressing trade frictions and policy formulation, this paper constructs a three-tier cross-border supply chain model comprising domestic suppliers, domestic manufacturers, and multinational manufacturers. It analyzes equilibrium decisions under tariff-free, unilateral tariff, and bilateral tariff scenarios. Using reverse induction, the optimal pricing and profits of supply chain members are determined, with a focus on analyzing the effects of key factors such as the tariff application stage, raw material costs, and market competition intensity. Findings reveal that tariffs influence upstream and downstream pricing through cost pass-through: when applied to final goods, suppliers gain bargaining power and raise wholesale prices; when applied to intermediate goods, suppliers are forced to lower prices to maintain sales volume. Manufacturers' selling prices and market demand are jointly regulated by cost and competition effects, exhibiting non-monotonic changes under bilateral tariffs that reflect the dynamic trade-off between cost-driven increases and demand contraction. Profit analysis indicates that when tariffs are applied to final goods, multinational manufacturers can pass on the tax burden by raising prices when raw material costs are low, potentially achieving higher profits than in a tariff-free scenario. When tariffs target intermediate goods, multinational manufacturers bear the brunt of the burden, exhibiting a "reverse pass-through" effect. Bilateral tariffs consistently represent a suboptimal choice for multinational manufacturers, demonstrating that retaliatory tariffs fail to improve their profitability. Under asymmetric tariff scenarios, the interaction between tariff intensity, costs, and competitive strength further influences corporate strategy choices.

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1. Introduction

Since China's accession to the World Trade Organization in 2001, China has primarily exported labor-intensive products to the United States, while the United States has exported technology-intensive products to China. Both nations have benefited from economic and trade cooperation. However, with persistent trade imbalances and an expanding trade deficit, the trade environment between China and the United States has gradually deteriorated. Since 2018, the United States has repeatedly imposed tariffs on Chinese imports, with rates ranging from 10% to 25% (Alfaro et al., 2025). In response, China has also imposed retaliatory tariffs on certain U.S. imports. The frequent emergence of tariff barriers has not only altered the pricing structure of cross-border goods but also profoundly impacted the production and operational decisions of multinational manufacturers (Cai et al., 2025).

The report of the 20th CPC National Congress noted that "currently, anti-globalization sentiments are on the rise, with unilateralism and protectionism markedly increasing". Some countries have employed inappropriate tariff policies to engage in trade protectionism, hindering the liberalization of international trade and undermining the international economic order(Luo et al., 2025). Tariff shocks have triggered global trade frictions and profoundly impacted manufacturing participation in global value chains(Zhao et al., 2025). These shocks have led to a gradual increase in the average tariff rate on imported manufacturing products worldwide, widening the gap between tariff and non-tariffed goods(Gu et al., 2025).

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Research on trade policy provides the theoretical foundation for this study. The theory of optimal tariffs, dating back to Johnson et al. (1953), shows that while a large country can improve its terms of trade by imposing unilateral tariffs, such actions invite retaliation, leaving all parties worse off. Bagwell and Staiger (1999) further formalize this logic in the context of trade agreements, and Ossa et al. (2014) quantifies it in a multi-industry setting. A growing body of empirical work examines the pass-through of tariffs to consumer prices. Amiti, Redding, and Weinstein (2019) and Fajgelbaum et al. (2020) find that the 2018–2019 U.S.–China trade war resulted in nearly complete pass-through of tariffs into U.S. domestic prices, with substantial welfare losses. Cavallo et al. (2021) further document systematic differences in tariff pass-through between the border and retail stores, depending on market structure and distribution channels. More recently, research has turned to the role of global value chains in shaping trade policy outcomes. Grossman et al. (2021) provide a theoretical framework illustrating how tariffs disrupt supply chain linkages, while Blanchard et al. (2023) empirically examine how supply chain integration shapes the formation of trade policy. Furthermore, trade policy uncertainty has been shown to reduce trade and welfare (Handley et al., 2017). However, these macro-level trade analyses often treat production as a single stage and treat tariffs as uniform border measures, leaving a critical gap in understanding how tariff shocks propagate through multi-tier supply chains and affect the strategic interactions among upstream suppliers and downstream manufacturers. This paper bridges this gap by examining tariff effects from a micro-level supply chain perspective.

Multinational manufacturers typically occupy a central position in cross-border supply chains, sourcing raw materials from upstream suppliers in different countries while selling products to multiple international markets(Ivanov et al., 2025). Tariffs, a common international trade protection measure, enhance domestic corporate competitiveness. However, imposed tariffs directly increase import prices, and these additional costs are passed up and down the supply chain, harming supply chain interests and consumer welfare(Li et al.,2024a). The imposition of import tariffs also increases the costs of procuring raw materials and intermediate products for enterprises in importing countries, thereby raising production costs for domestic enterprises that utilize imported inputs. These cost increases drive up both domestic market prices and export prices, weakening the competitiveness of products in both domestic and international markets and harming the interests of domestic enterprises. Simultaneously, complex strategic interactions exist between upstream and downstream enterprises. Pricing decisions made by manufacturers and suppliers under a tariff environment not only determine their respective profits but also impact on the overall stability of the supply chain.

Regarding the impact of different tariff structures on decision-making among cross-border supply chain members, the following research questions are proposed:

(1) How do tariffs influence optimal pricing decisions for upstream suppliers and downstream manufacturers in cross-border supply chains through cost pass-through under three structures, zero tariffs, single-directional tariffs, and double-directional tariffs?

(2) How do demand allocation and profits among supply chain members change when tariffs are applied to final products versus intermediate inputs?

(3) Under trade friction and retaliatory tariffs, which is more beneficial for the profit enhancement: single-directional tariffs or retaliatory double-directional tariffs? How do asymmetric tariff structures and costs influence firms' optimal strategy selection?

To address these issues, this paper examines a cross-border supply chain comprising a domestic supplier, a domestic manufacturer, and a multinational manufacturer. The domestic supplier provides raw materials to both the domestic manufacturer and the multinational manufacturer, with both manufacturers selling their products to the domestic market. To attract more consumers, the domestic market imposes additional import tariffs on the multinational manufacturer. Simultaneously, the multinational manufacturer also imposes additional import tariffs on the domestic supplier. The study analyzes how different tariff structures influence the decision-making of supply chain members.

Research indicates that when tariffs are imposed on final goods, multinational manufacturers face increased marginal costs and higher selling prices, while suppliers gain greater bargaining power, leading to rising wholesale prices. Conversely, when tariffs target intermediate goods, multinational manufacturers incur higher procurement costs, compelling suppliers to lower wholesale prices to maintain sales volume. Under reciprocal tariffs, the combined cost effects cause wholesale prices to be positively influenced by tariffs on final goods and negatively impacted by tariffs on intermediate goods. As a result, the selling prices of manufacturers in both countries exhibit a non-monotonic pattern of rising first and then falling, reflecting a dynamic trade-off between cost-push inflation and demand contraction.

Regarding the impact of different tariff application points on demand allocation and profit changes, research indicates that tariffs redistribute demand by altering prices for manufacturers in both countries, thereby guiding consumers toward new choices. When tariffs are applied to final goods, multinational manufacturers can pass on the tax burden by raising prices when raw material costs are low, resulting in profits that may even exceed those in a tariff-free scenario. Conversely, when tariffs target intermediate goods, multinational manufacturers bear the brunt of the tariff burden, experiencing lower profits

than in a tariff-free environment, a phenomenon known as “reverse pass-through”. For multinational manufacturers, when raw material costs are low, the scenario where tariffs are applied to final goods proves more advantageous; when costs are high, the scenario where tariffs target intermediate goods yields better results. Bilateral tariffs consistently represent a suboptimal choice, indicating that tariff retaliation fails to improve profitability. Instead, the accumulation of costs exacerbates competitive disadvantages. For suppliers, downstream tariffs indirectly benefit upstream players through competitive effects, while upstream tariffs directly erode profits. Under asymmetric tariffs, the interaction between tariff intensity, costs, and competitive intensity further shapes firms' optimal strategy choices.

This study constructs a unified analytical framework that distinguishes between tariffs on final goods and intermediate goods while encompassing both unilateral and bilateral taxation. It reveals differentiated transmission pathways and competitive effects arising from tariffs applied at different stages, uncovers phenomena such as the “reverse transmission” of tariff burdens, and enriches the theoretical perspectives on cross-border supply chain tariff research. Simultaneously, it provides strategic guidance for multinational corporations to optimize pricing and procurement decisions, suggesting that firms should dynamically adjust strategies based on tariff application stages, cost structures, and market competition intensity. For policymakers, this study indicates that tariff policies carry significant supply chain linkage effects. Retaliatory tariffs often fail to achieve their intended protective goals and may instead exacerbate competitive disadvantages for domestic firms. Policy design should prioritize coordination and structural coherence to prevent distortions in industrial chains.

The remaining structure of this paper is as follows. Section 2 reviews the relevant literature. Section 3 introduces research assumptions and modes. Section 4 analyzes the equilibrium structure, discussing how different tariff structures affect the pricing decisions and profits of cross-border supply chain members. Section 5 expands the research by examining how firms adjust their optimal strategy choices under asymmetric tariff scenarios. Section 6 presents the conclusions of the entire paper.

2. Literature review

This section reviews three streams of literature to position our study: operational decisions in cross-border supply chains, the impact of tariffs on supply chain decisions, and firms' strategic responses to tariff uncertainty.

2.1. Operational decision-making in cross-border supply chain

Cross-border supply chain refers to the global movement and exchange of goods, services, capital, and information through effective supply chain management. Existing research has examined various factors affecting corporate decisions. Merzifonluoglu (2024) reveals the critical role of information quality and risk aversion in building resilient procurement strategies. Yu et al. (2026) propose an eco-efficiency assessment method for global supply chain activities. Zhang et al. (2023, 2024) find that information sharing on cross-border e-commerce platforms intensifies price competition with local suppliers. Guo et al. (2025) develop optimization frameworks to reduce operational costs under uncertain procurement prices. They systematically analyzed how enterprises can reduce total operational costs in cross-border supply chains through advanced procurement and inventory strategies under uncertain procurement pricing conditions. Further studies extend this line of inquiry to emerging operational challenges. Niu et al. (2025a) analyze how tax differentials and risk aversion shape data-sharing strategies. Huang et al.(2024) examine remanufacturing mode choices for multinational OEMs considering cost differences and cross-border recycling expenses. Chen and Duan (2023) investigate supplier information disclosure in response to NGO scrutiny. Cao and Sun (2025) analyze how brand spillover effects influence domestic versus overseas procurement decisions. Xin et al. (2025) study the impact of carbon policies on production pricing and quota allocation. Liu et al. (2024) and Liu et al. (2025) examine contract manufacturer encroachment and power battery recycling integration, respectively. Existing research has examined various factors influencing operational decisions in cross-border supply chains, including procurement strategies, eco-efficiency, information sharing, logistics modes, data transfer, and remanufacturing choices. However, most studies focus on internal efficiency or specific external factors at the strategic and performance levels. How changes in the external policy environment affect strategic interactions and equilibrium outcomes between upstream and downstream supply chain members remain underexplored.

2.2. Impacts of tariffs on supply chain decision

A growing stream of research explicitly considers how tariffs and tax differentials influence supply chain design and member behavior. Deng et al. (2023) show that global tax differentials and organizational structures significantly affect supply chain profitability. Huang et al. (2023) find that firms are more likely to reshore production when tax differentials are small and overseas risks are high. Chen et al. (2022) analyze the effects of tariffs and premiums on global manufacturers' sourcing decisions. Li et al. (2023) examine how tariffs and sales taxes influence OEMs' remanufacturing choices. Li et al. (2024b) investigate the joint effects of tariffs and carbon taxes on multinational closed-loop supply chains (Xue, 2024). Qu and Raff(2023) show that two-part tariff contracts can mitigate inventory hoarding and the bullwhip effect. The study found that upstream firms can mitigate strategic inventory hoarding by downstream firms through two-tier pricing contracts, thereby reducing production volatility and alleviating the bullwhip effect.

Tariff types also influence firms' pricing strategies and profit allocation. Niu et al. (2022) compare ad valorem and specific tariffs for quality-differentiated cross-border e-tailers. He et al. (2023) analyze financing strategies in vertically held transnational supply chains under tax asymmetry. Yu et al. (2024) examine how global manufacturers respond to unauthorized parallel imports under import tax differentials. These studies illuminate how tariffs affect corporate behavior through cost pass-through and changes in competitive structure. However, they tend to focus on single decision dimensions or comparative analyses of tariff rates, with limited attention to the differential effects of tariffs applied at various stages of the supply chain, particularly in unilateral versus bilateral settings.

2.3. Strategic responses to tariff uncertainty and risk

Recent research has begun to address how firms strategically adapt to tariff shocks and trade policy uncertainty. Ahmadi Digehsara et al. (2025) find that strategic alliances can improve supply chain profitability under tariff surges and trade quotas, particularly in highly uncertain environments. Lai et al. (2023) show that tariff increases raise manufacturers' product prices while lowering suppliers' raw material prices, reducing profits for all supply chain members, and propose a cost-sharing mechanism to mitigate such shocks. Wu et al. (2024) find that tariffs exert a non-monotonic effect on firms' incentives to develop new contract manufacturers, with moderate tariff levels providing stronger incentives than high tariffs. Niu et al. (2025b) show that tax differentials, market potential, and competitive channel intensity jointly influence multinationals' production location decisions and transfer pricing strategies. Hu et al. (2026) analyze how duty collection strategies reshape competition between parallel importers and authorized retailers by influencing consumers' payment expectations and waiting costs.

Current research has examined the impact of tariffs on various supply chain segments from multiple perspectives, including tax differentials, repatriation decisions, procurement strategies, remanufacturing choices, and risk hedging. These studies reveal that tariffs influence corporate behavior through cost pass-through, changes in competitive structure, and risk expectations. However, most focus on single decision dimensions or comparative analyses of tariff rates, with limited attention to tariff shocks across different trade segments. How tariffs interact with upstream cost adjustments and downstream market competition to shape overall supply chain equilibrium, particularly under unilateral versus bilateral settings, remains underexplored.

Given the prevalence of trade frictions and differentiated tariff policies, understanding how tariffs affect upstream suppliers' bargaining power and manufacturers' pricing decisions through changes in downstream competition, cost pass-through, and market demand is of theoretical and practical importance. To address this, we have constructed a three-tier cross-border supply chain game model involving suppliers and manufacturers from Country A and manufacturers from Country B. By comparing equilibrium outcomes under no tariffs, unilateral tariffs, and bilateral tariffs, we elucidate the mechanisms through which tariffs influence supply chain decisions. This analysis provides theoretical foundations for firms navigating complex tariff environments and offers policy insights for designing coordinated trade policies. Table 1 lists the gap between this study and related literature in main topics.

Table 1
Comparison with the most relevant papers.

Representative articles	Pricing decision	Competitive shift	Tariff transmission	Asymmetric tariff	Manufacturer strategy
Deng et al. (2023)	√		√		
Huang et al. (2023)		√			√
Chen et al. (2022)	√	√			√
Li et al. (2023)	√		√		√
Li et al. (2024a)	√		√		√
Niu et al. (2022)	√	√			√
Wu et al. (2024)		√		√	√
Lai et al. (2023)	√		√		√
This study	√	√	√	√	√

3. Research assumptions and models

This study examines a scenario where supplier s_A in Country A provides raw materials to manufacturers in both Countries A and B at a wholesale price w_A. The supplier's raw material cost is denoted as c. Manufacturers in Countries A and B sell their products to the Country A market at prices p_A and p_B, respectively. Four scenarios are examined: no tariffs (Model NN), Country A imposing tariffs on Country B (Model TN), Country B imposing tariffs on Country A (Model NT), and reciprocal tariffs between Countries A and B (Model TT). The analysis tracks changes in prices, demand, and profits across supply chain members under each scenario. The supply chain structure is illustrated in Fig. 1.

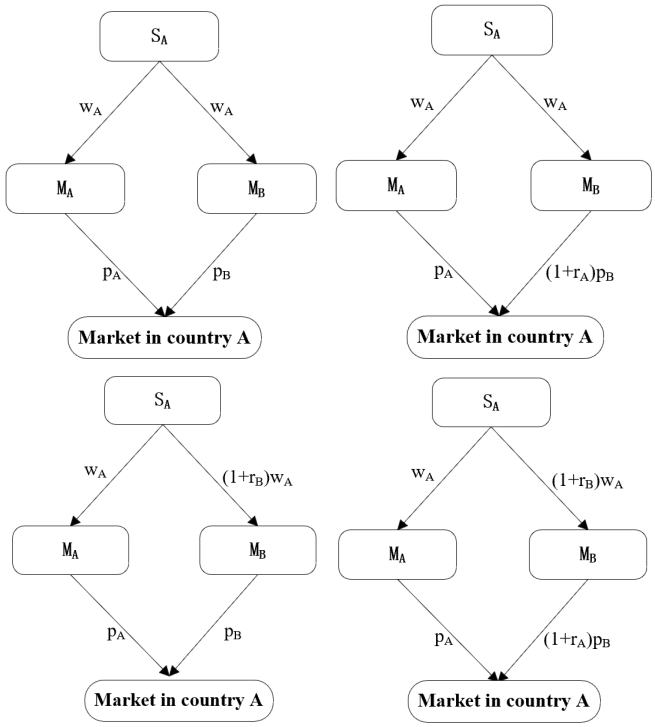

Fig. 1. Supply Chain Structure

For explanations of relevant symbols, see Table 2.

3.1 The benchmark model： No-Tariff Scenario (NN)

In this scenario NN, a supplier in Country A sells raw materials to both a manufacturer in Country A and a manufacturer in Country B, with both manufacturers selling their products to the Country A market. The inverse demand function for the Country A market is defined as:$p_A = a - q_A - \lambda q_B$,$p_B = a - q_B - \lambda q_A$.$a$ represents market size,$a \in (0,1]$, λrepresents the intensity of competition between suppliers in countries A and B,$\lambda \in (0,1]$.The profit functions for Country A suppliers, Country A manufacturers, and Country B manufacturers can be expressed as:$\pi_{sA}^{NN} = (w_A - c)q_A +$ （$w_A - c)q_B$,$\pi_{MA}^{NN} = (p_B - w_A)q_A$,$\pi_{MB}^{NN} = (p_B - w_B)q_B$. Using reverse induction, we obtain Lemma 1.

Table 2
Symbol Explanations

Symbol	Meaning
s_A	Supplier from Country A
M_A, M_B	Manufacturer in Country A, Manufacturer in Country B
w_A	Wholesale price of raw materials sold by suppliers in Country A
c	Raw material costs for suppliers in Country A
p_A	Selling price of products sold by Manufacturer A to Country A
p_B	Selling price of products from Country B to Country A
q_A, q_B	Market demand for manufacturers in Countries A and B
a	Market Size
λ	Competitive Intensity Between Manufacturers in Countries A and B
r_A, r_B	The tariffs imposed by Country A on Country B, and the tariffs imposed by Country B on Country A
$\pi_{sA}, \pi_{MA}, \pi_{MB}$	The profit of Supplier A, The profit of Manufacturers A and B

Lemma 1. When consumers simultaneously purchase domestic and imported products, the equilibrium wholesale price is$w_A^{NN} = \frac{a+c}{2}$;The equilibrium selling price is$p_A^{NN} = \frac{3a+c+a\lambda+c\lambda}{4+2\lambda}$,$p_B^{NN} = \frac{3a+c+a\lambda+c\lambda}{4+2\lambda}$;The equilibrium demand is $q_A^{NN} = \frac{a-c}{4+2\lambda}$,$q_B^{NN} = \frac{a-c}{4+2\lambda}$.

From Lemma 1, the equilibrium profits are $\pi_{sA}^{NN} = \frac{(a-c)^2}{2(2+\lambda)}$, $\pi_{MA}^{NN} = \frac{(a-c)^2}{4(2+\lambda)^2}$ and $\pi_{MB}^{NN} = \frac{(a-c)^2}{4(2+\lambda)^2}$.

3.2 Country A imposes single-direction tariffs（TN）

In this scenario, when Country B's manufacturers sell products to Country A, they must pay a tariff rate of r_A. The profit functions for each supply chain member are expressed as:$\pi_{sA}^{TN} = (w_A - c)q_A + (w_A - c)q_B$,$\pi_{MA}^{TN} = (p_A - w_A)q_A$,$\pi_{MB}^{TN} = [(1 + r_A)p_B - w_A]q_B$. Using reverse induction, we obtain Lemma 2.

Lemma 2. When Country A imposes tariffs on Country B, the equilibrium wholesale price is $w_A^{TN} = \frac{c}{2} + \frac{a(1+r_A)}{2+r_A}$;The equilibrium selling price is $p_A^{TN} = \frac{c(2+r_A)\left((-2+\lambda)(1+\lambda)+r_A(-2+\lambda^2)\right)+2a(1+r_A)\left(-6+\lambda+\lambda^2+r_A(-4+\lambda+\lambda^2)\right)}{2(1+r_A)(2+r_A)(-4+\lambda^2)}$ and $p_B^{TN} = \frac{c(2+r_A)(2+(1+r_A-\lambda)\lambda)+2a(1+r_A)\left(2r_A-(-2+\lambda)(3+\lambda)\right)}{2(1+r_A)(2+r_A)(4-\lambda^2)}$. The equilibrium demand is $q_A^{TN} = \frac{c\left(1+r_A-\frac{\lambda}{2}\right)+\frac{a(1+r_A)(-2+\lambda+r_A\lambda)}{2+r_A}}{(1+r_A)(-4+\lambda^2)}$ and $q_B^{TN} = \frac{2a(1+r_A)(2+2r_A-\lambda)+c(2+r_A)(-2+\lambda+r_A\lambda)}{2(1+r_A)(2+r_A)(4-\lambda^2)}$.

From Lemma2, we can get $\pi_{sA}^{TN} = \frac{\left(-2a(1+r_A)+c(2+r_A)\right)^2}{4(1+r_A)(2+r_A)(2+\lambda)}$; $\pi_{MA}^{TN} = \frac{\left(c(2+r_A)(2+2r_A-\lambda)+2a(1+r_A)(-2+\lambda+r_A\lambda)\right)^2}{4(1+r_A)^2(2+r_A)^2(-4+\lambda^2)^2}$ and $\pi_{MB}^{TN} = \frac{\left(2a(1+r_A)(2+2r_A-\lambda)+c(2+r_A)(-2+\lambda+r_A\lambda)\right)^2}{4(1+r_A)(2+r_A)^2(-4+\lambda^2)^2}$.

Corollary 1. The impact of tariff changes on supply chain equilibrium outcomes:

（1）$\frac{\partial w_A^{TN}}{\partial r_A} > 0$; （2）When $r_{A1} < r_A < 1$, $\frac{\partial p_A^{TN}}{\partial r_A} > 0$,otherwise $\frac{\partial p_A^{TN}}{\partial r_A} < 0$; $\frac{\partial p_B^{TN}}{\partial r_A} < 0$;
（3）$\frac{\partial q_A^{TN}}{\partial r_A} < 0$, $\frac{\partial q_B^{TN}}{\partial r_A} > 0$; （4）$\frac{\partial \pi_{sA}^{TN}}{\partial r_A} > 0$,When $r_{A2} < r_A < 1$, $\frac{\partial \pi_{MA}^{TN}}{\partial r_A} > 0$,otherwise $\frac{\partial \pi_{MA}^{TN}}{\partial r_A} < 0$; $\frac{\partial \pi_{MB}^{TN}}{\partial r_A} > 0$.

Corollary 1 demonstrates that under a scenario where Country A imposes unilateral import tariffs, the tariffs alter the competitive position between manufacturers in both countries by increasing the marginal costs of Country B's manufacturers. Furthermore, through vertical supply chain transmission mechanisms, tariffs influence the pricing behavior of upstream suppliers. Changes in tariffs not only trigger a realignment of sales prices and market demand but also lead to a redistribution of profits among supply chain members. The varying trends of relevant variables across different tariff ranges indicate that tariff intensity exhibits a threshold effect, with its economic consequences determined by the relative strength of cost shock effects versus competition-weakening effects.

3.3 Country B imposes single-direction tariffs（NT）

In this scenario, when Country A's supplier sells raw materials to Country B's manufacturer, it incurs a tariff rate of r_B. The profit functions for each member of the supply chain are expressed as:$\pi_{sA}^{NT} = (w_A - c)q_A + [(1+r_B)w_A - c]q_B$,$\pi_{MA}^{NT} = (p_A - w_A)q_A$,$\pi_{MB}^{NT} = [p_B - (1+r_B)w_A]q_B$. Using reverse induction, we obtain Lemma 3.

Lemma 3. In the scenario where Country B imposes tariffs on Country A, the equilibrium wholesale price is $w_A^{NT} = \frac{(a+c)(2+r_B)(2-\lambda)}{4\left(2+2r_B+r_B^2-(1+r_B)\lambda\right)}$; The equilibrium sales price is $p_A^{NT} = \frac{1}{4}\left(\frac{(a+c)(2+r_B)}{1+r_B} + \frac{2(a-c)}{2+\lambda} + \frac{(a+c)r_B}{(1+r_B)\left(2+2r_B+r_B^2-(1+r_B)\lambda\right)}\right)$, $p_B^{NT} = \frac{1}{4}\left((a+c)(2+r_B) + \frac{2(a-c)}{2+\lambda} + \frac{(a+c)r_B(1+r_B)^2}{-2+\lambda+r_B(-2-r_B+\lambda)}\right)$; The equilibrium demand is $q_A^{NT} = \frac{a-c}{4+2\lambda} + \frac{(a+c)r_B(1+r_B)}{4\left(2+2r_B+r_b^2-(1+r_B)\lambda\right)}$ and $q_B^{NT} = \frac{1}{4}\left(\frac{2(a-c)}{2+\lambda} + \frac{(a+c)r_B}{-2+\lambda+r_B(-2-r_B+\lambda)}\right)$.

From Lemma3,we can get $\pi_{sA}^{NT} = \frac{1}{8}\left(\frac{4(a-c)^2}{2+\lambda} + \frac{(a+c)^2r_B^2}{-2+\lambda+r_B(-2-r_B+\lambda)}\right)$,$\pi_{MA}^{NT} = \frac{\left(c(2+r_B)(-2+\lambda+r_B\lambda)+a\left(4-2\lambda+r_B(6-\lambda+r_B(4+\lambda))\right)\right)^2}{16(2+\lambda)^2\left(-2+\lambda+r_B(-2-r_B+\lambda)\right)^2}$,$\pi_{MB}^{NT} = \frac{\left(-2a(2+r_B+r_B^2)+c(2+r_B)(2+2r_B-\lambda)+a(2+3r_B)\lambda\right)^2}{16(2+\lambda)^2\left(-2+\lambda+r_B(-2-r_B+\lambda)\right)^2}$.

Corollary 2. The impact of tariff changes on supply chain equilibrium outcomes:

（1）$\frac{\partial w_A^{NT}}{\partial r_B} < 0$; （2）$\frac{\partial p_A^{NT}}{\partial r_B} < 0$, when$0 < r_B < r_{B1}$, $\frac{\partial p_B^{NT}}{\partial r_B} > 0$,otherwise $\frac{\partial p_B^{NT}}{\partial r_B} < 0$;
（3）$\frac{\partial q_A^{NT}}{\partial r_B} > 0$, $\frac{\partial q_B^{NT}}{\partial r_B} < 0$; （4）$\frac{\partial \pi_{sA}^{NT}}{\partial r_B} < 0$, $\frac{\partial \pi_{MA}^{NT}}{\partial r_B} > 0$, when$r_{B2} < r_B < 1$, $\frac{\partial \pi_{MB}^{NT}}{\partial r_B} > 0$, otherwise $\frac{\partial \pi_{MB}^{NT}}{\partial r_B} < 0$.

Corollary 2 analyzes the impact of tariff changes on supply chain equilibrium outcomes under a scenario where Country B imposes unilateral tariffs on Country A. The tariff increase raises raw material procurement costs for Country B manufacturers, suppressing their demand for upstream materials. To maintain transaction volumes, Country A suppliers respond by lowering prices, causing wholesale prices to decline as tariffs rise. Regarding sales prices, manufacturers in Country A lower their prices as wholesale costs decrease and marginal costs decline. At lower tariff levels, the cost-push effect dominates, prompting manufacturers in Country B to pass on part of the cost by raising their sales prices. However, once tariffs exceed a critical threshold, the demand-shrinkage effect intensifies, forcing manufacturers in Country B to reduce their sales prices to preserve market share. The tariff hike improves Country A manufacturers' competitive position, boosting their market demand. Conversely, Country B manufacturers face declining demand due to rising raw material costs and weakened price competitiveness. Overall, under Country B's unilateral taxation scenario, the tariff shock first impacts intermediate goods

trade. Through vertical cost pass-through and horizontal competitive substitution mechanisms, it reshapes the internal supply chain's price structure, demand distribution, and profit dynamics.

3.4 Two-way tariffs（TT）

In this scenario, when Country A's supplier sells raw materials to Country B's manufacturer, it incurs a tariff rate of r_B. When Country B's manufacturer sells products to Country A, it incurs a tariff rate ofr_A. The tariffs levied by both countries are equal, meaning $r_A = r_B$. The profit functions for each member are expressed as: $\pi_{sA}^{TT} = (w_A - c)q_A + [(1 + r_B)w_A - c]q_B$, $\pi_{MA}^{TT} = (p_A - w_A)q_A$, $\pi_{MB}^{TT} = [(1 + r_A)p_B - (1 + r_B)w_A]q_B$. Using reverse induction, we obtain Lemma 4.

Lemma 4. When Countries A and B impose tariffs on each other, the equilibrium wholesale price is $w_A^{TT} = \frac{(a(1+r_A)(2+r_B)+c(2+r_A+r_B))(-2+\lambda)}{-4(2+r_A+r_B(2+r_B))+2(2+r_A)(1+r_B)\lambda}$; The equilibrium sales price is

$$p_A^{TT} = \frac{a(1+r_A)\left(-2\left(6+r_A(4+r_B)+r_B(5+2r_B)\right)+(2+2r_A-r_B)(1+r_B)\lambda+(1+r_A)(2+r_B)\lambda^2\right)+c(2+r_A+r_B)\left(-2-(1+r_B)\lambda+\lambda^2+r_A\left(-2+\lambda^2\right)\right)}{2(1+r_A)(2+\lambda)\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)},$$

$$p_B^{TT} = \frac{-c(2+r_A+r_B)\left(2(1+r_B)+(1+r_A)\lambda-(1+r_B)\lambda^2\right)+a(1+r_A)\left(-2\left(6+2r_A+r_B(7+3r_B)\right)+(2+(3+r_A)r_B)\lambda+(1+r_B)(2+r_B)\lambda^2\right)}{2(1+r_A)(2+\lambda)\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)};$$

The equilibrium demand is

$$q_A^{TT} = \frac{c(2+r_A+r_B)(2+2r_A-(1+r_B)\lambda)+a(1+r_A)(-4+2(-3+r_A-2r_B)r_B+(2+2r_A-r_B)(1+r_B)\lambda)}{2(1+r_A)(2+\lambda)\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)},$$

$$q_B^{TT} = \frac{-c(2+r_A+r_B)(-2-2r_B+\lambda+r_A\lambda)+a(1+r_A)(-2(2+2r_A+r_B+r_B^2)+(2+(3+r_A)r_B)\lambda)}{2(1+r_A)(2+\lambda)\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)}.$$

From Lemma 4, we can get

$$\pi_{sA}^{TT} = \frac{a^2(1+r_A)^2(2+r_B)^2(-2+\lambda)+c^2(2+r_A+r_B)^2(-2+\lambda)-2ac(1+r_A)\left(4(-2+\lambda)+r_A(-4+2r_B+2\lambda+3r_B\lambda)-r_B\left(8-4\lambda+r_B(6+\lambda)\right)\right)}{4(1+r_A)(2+\lambda)\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)};$$

$$\pi_{MA}^{TT} = \frac{\left(c(2+r_A+r_B)(2+2r_A-(1+r_B)\lambda)+a(1+r_A)(-4+2(-3+r_A-2r_B)r_B+(2+2r_A-r_B)(1+r_B)\lambda)\right)^2}{4(1+r_A)^2(2+\lambda)^2\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)^2}, \text{ and}$$

$$\pi_{MB}^{TT} = \frac{\left(c(2+r_A+r_B)(-2-2r_B+\lambda+r_A\lambda)+a(1+r_A)\left(2(2+2r_A+r_B+r_B^2)-(2+(3+r_A)r_B)\lambda\right)\right)^2}{4(1+r_A)(2+\lambda)^2\left(-2\left(2+r_A+r_B(2+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)^2}.$$

Corollary 3. The impact of tariff changes on supply chain equilibrium outcomes:

（1）$\frac{\partial w_A^{TT}}{\partial r_A} > 0, \frac{\partial w_A^{TT}}{\partial r_B} < 0$; （2）When $0 < r_A < r_{A2}$, $\frac{\partial p_A^{TT}}{\partial r_A} > 0$, otherwise $\frac{\partial p_A^{TT}}{\partial r_A} < 0$,when $0 < r_B < r_{B3}$, $\frac{\partial p_A^{TT}}{\partial r_B} > 0$, otherwise$\frac{\partial p_A^{TT}}{\partial r_B} < 0$; when $0 < r_A < r_{A3}$, $\frac{\partial p_B^{TT}}{\partial r_A} < 0$, otherwise $\frac{\partial p_B^{TT}}{\partial r_A} > 0$, when $r_{B4} < r_B < 1$, $\frac{\partial p_B^{TT}}{\partial r_B} < 0$, otherwise $\frac{\partial p_B^{TT}}{\partial r_B} > 0$; （3）$\frac{\partial q_A^{TT}}{\partial r_A} < 0$, when $r_{B5} < r_B < 1$, $\frac{\partial q_A^{TT}}{\partial r_B} > 0$, otherwise $\frac{\partial q_A^{TT}}{\partial r_B} < 0$; $\frac{\partial q_B^{TT}}{\partial r_A} > 0$, $\frac{\partial q_B^{TT}}{\partial r_B} > 0$; （4）$\frac{\partial \pi_{sA}^{TT}}{\partial r_A} > 0$, when $0 < r_B < r_{B6}$, $\frac{\partial \pi_{sA}^{TT}}{\partial r_B} > 0$, otherwise $\frac{\partial \pi_{sA}^{TT}}{\partial r_B} < 0$; when $r_{A4} < r_A < 1$, $\frac{\partial \pi_{MA}^{TT}}{\partial r_A} > 0$, otherwise $\frac{\partial \pi_{MA}^{TT}}{\partial r_A} < 0$, when $r_{B7} < r_B < 1$, $\frac{\partial \pi_{MA}^{TT}}{\partial r_B} > 0$, otherwise $\frac{\partial \pi_{MA}^{TT}}{\partial r_B} < 0$; when $r_{A5} < r_A < 1$, $\frac{\partial \pi_{MB}^{TT}}{\partial r_A} > 0$, otherwise $\frac{\partial \pi_{MB}^{TT}}{\partial r_A} < 0$, when $r_{B8} < r_B < 1$, $\frac{\partial \pi_{MB}^{TT}}{\partial r_B} > 0$, otherwise $\frac{\partial \pi_{MB}^{TT}}{\partial r_B} < 0$.

Corollary 3 illustrates that in a double-tariff scenario, tariffs simultaneously affect both intermediate goods and final products. On one hand, when Country A increases tariffs on Country B, it weakens the market competitiveness of Country B's manufacturers, thereby enhancing the bargaining power of Country A's suppliers over domestic manufacturers and causing wholesale prices to rise as r_A increases. Conversely, when Country B increases tariffs on Country A, it raises the export costs of intermediate goods, compresses the scale of raw material demand, and causes wholesale prices to fall as r_B increases. On the other hand, both countries' manufacturers exhibit a threshold effect in how their sales prices and profits respond to tariff changes: at low tariffs, cost-push effects dominate, and firms tend to pass on part of the tax burden by raising prices. However, once tariffs exceed a threshold, demand contraction and competitive substitution effects intensify, causing prices and profits to decline. Overall, changes in tariff intensity reshape price structures, demand allocation, and profits by simultaneously affecting upstream costs and downstream market competition.

4. Optimal decision-making and equilibrium analysis

This section analyzes and discusses equilibrium outcomes by comparing results across different scenarios.

4.1. Analysis of supply's pricing decisions

Comparing the wholesale prices of suppliers across four scenarios establishes proposition 1.

Proposition 1. In the four tariff scenarios, the supplier's equilibrium wholesale price satisfies the following relationship:（1）$w_A^{TN} > w_A^{NN}$;（2）$w_A^{NT} < w_A^{NN}$;（3）当$c_1 < c$时,$w_A^{TT} < w_A^{NN}$;（4）当$c_2 < c$时,$w_A^{TN} < w_A^{TT}$

Proposition 1 reveals that when Country A imposes import tariffs on Country B, the tariffs directly impact the final product sales stage of Country B's manufacturers. This increases their marginal costs and weakens their price competitiveness in Country A's market. Consequently, it indirectly strengthens the bargaining power of Country A's suppliers relative to downstream manufacturers, enabling them to raise wholesale prices. When Country B imposes import tariffs on Country A, the tariffs are applied to the intermediate goods trade segment. This directly increases raw material procurement costs for Country B manufacturers, suppressing their demand for upstream raw materials. To maintain sales volume, Country A suppliers are forced to lower wholesale prices. Under a bilateral tariff scenario, suppliers' wholesale prices are jointly influenced by both countries' tariffs. When raw material costs exceed a certain threshold, the negative effect of Country B's tariff becomes dominant, causing prices to fall below those in a tariff-free scenario. This outcome demonstrates that the point of tariff application and cost structure jointly determines suppliers' pricing decisions. Tariffs do not invariably benefit upstream enterprises; their ultimate impact depends on the transmission path within the supply chain and the capacity to absorb costs.

4.2. Analysis of manufacturers' pricing decisions

When Country A imposes import tariffs on Country B, the tariffs increase the marginal cost for Country B manufacturers to enter Country A's market, thereby altering the competitive structure of the market. Compared to a tariff-free scenario, Country A's manufacturers gain a stronger relatively competitive position in their domestic market, enhancing their pricing power. Since tariffs imposed by Country B on Country A do not directly affect the sales of Country A's manufacturers in their home market, comparing sales prices under tariff-free, unilateral tariffs by Country A, and bilateral tariffs establishes proposition 2.

Proposition 2.（1）When $0 < c < c_3$, imposing unilateral tariffs on Country B by Country A will increase the sales price of Country A's manufacturers compared to the tariff-free scenario, i.e.,$p_A^{NN} < p_A^{TN}$;（2）The sales price of Country A's manufacturers under the unilateral tariff scenario is higher than under the bilateral tariff scenario, i.e.,$p_A^{TN} > p_A^{TT}$.

Proposition 2 indicates that Country A manufacturers' pricing depends on the impact of tariffs on competitors' costs, upstream prices, and market demand structure. Under a one-way tariff scenario imposed by Country A, the competitive pressure faced by Country A manufacturers is reduced, and the intensity of market competition decreases. When raw material costs are low, the expansion of pricing space driven by increased competitor costs becomes dominant. Therefore, compared to a tariff-free scenario, Country A manufacturers tend to raise their selling prices. Under a bilateral tariff scenario, Proposition 1 explains that cost constraints in the intermediate goods segment weaken Country A manufacturers' cost advantage through vertical transmission. Simultaneously, bilateral tariffs often accompany tighter market demand conditions, subjecting firms to stronger demand elasticity constraints when pricing. Consequently, compared to Country A imposing unilateral tariffs, the optimal selling price for Country A manufacturers is lower under bilateral tariffs.

Contrary to manufacturers in Country A, manufacturers in Country B often bear the direct impact of tariff adjustments. Therefore, it is necessary to compare sales prices under tariff-free conditions with those under two unidirectional tariff scenarios to analyze the extent of unilateral policy impacts on their pricing. Furthermore, comparing unidirectional tariffs with bilateral tariff scenarios allows for analyzing the amplifying effects of overlapping tariffs in a trade war context, as illustrated in proposition 3.

Proposition 3.（1）When $\lambda_1 < \lambda < 1$, imposing unilateral tariffs from Country A on Country B increases the sales price for Country B's manufacturers compared to the tariff-free scenario, i.e.,$p_B^{TN} > p_B^{NN}$;（2）When $0 < \lambda < \lambda_2$, the sales price under unilateral tariffs imposed by Country B is higher than the tariff-free sales price, i.e.,$p_B^{NT} > p_B^{NN}$;（3）when $0 < c < c_4$, the sales price for Country B's manufacturers in the bilateral tariff scenario is higher than in the unilateral tariff scenario imposed by Country A, i.e.,$p_B^{TT} > p_B^{TN}$.

Proposition 3(1) demonstrates that under a scenario where Country A imposes one-way tariffs, the tariffs increase the unit cost for Country B manufacturers to sell products in Country A's market. When firms face higher marginal costs, the first-order condition for profit maximization requires raising the sales price. Therefore, within a certain range of competitive intensity, Country B manufacturers' sales prices are higher compared to a tariff-free scenario. Proposition 3(2) demonstrates that when competition intensity is low, firms possess greater flexibility to adjust prices in the market, enabling them to shift part of the cost pressure through price increases. This occurs because in a scenario where Country B imposes unilateral tariffs, the tariffs only affect the intermediate goods trade segment, raising Country B manufacturers' raw material procurement costs. The increase in raw material costs elevates their marginal production costs, thereby prompting firms to raise selling prices under profit-maximization conditions. Further comparison between Country A's unilateral and bilateral tariff scenarios reveals that under bilateral tariffs, Country B manufacturers face dual cost constraints from both final product import duties and intermediate goods procurement tariffs, resulting in higher marginal cost levels than under unilateral tariffs. When raw material costs are low, the cost-addition effect dominates pricing decisions, leading to higher sales prices under bilateral tariffs

than under Country A's unilateral tariff scenario. Proposition 3 indicates that regardless of whether tariffs are applied to final products or intermediate inputs, their impact is fundamentally reflected in equilibrium prices through changes in firms' marginal costs. When tariffs exist simultaneously across multiple stages, the aggregation of cost constraints further amplifies the magnitude of price adjustments.

4.3. Optimal demand analysis for manufacturers

Since tariffs affect the market positions of manufacturers in both countries by altering costs and competitive landscapes, their effects ultimately manifest as a redistribution of demand. Therefore, comparing the equilibrium demand for Country A's manufacturers under different scenarios, proposition 4.

Proposition 4. When raw material costs satisfy$c_5 < c < c_6$,（1）in the tariff-free scenario, the demand from Country A's manufacturers exceeds the market demand under Country A's unilateral tariff on Country B, i.e.,$q_A^{NN} > q_A^{TN}$;（2）When $a_1 < a \leq 1$, the market demand under Country A's unilateral tariff scenario is less than that under the bilateral tariff scenario, i.e.,$q_A^{TN} < q_A^{TT}$.

In the comparison between a tariff-free scenario and a scenario where Country A imposes unilateral tariffs, when raw material costs fall within a certain range, demand from Country A manufacturers is higher in the tariff-free scenario than in the unilateral tariff scenario. This occurs because, after Country A imposes tariffs on Country B, although Country B manufacturers' sales costs increase, as demonstrated in Proposition 2 above, Country A manufacturers will correspondingly raise their sales prices at equilibrium. This price increase dampens the purchasing willingness of some consumers, thereby suppressing domestic demand. When raw material costs are in the medium range, the negative impact of price adjustments on demand outweighs the market share transfer effect resulting from competitors' cost increases. This outcome demonstrates that firm demand depends not only on relative competitive position but also on constraints imposed by their own pricing strategy adjustments. Comparing Country A's unilateral tariff with the bilateral tariff scenario reveals that under bilateral tariffs, Country B manufacturers face simultaneous cost constraints on both final products and intermediate goods. Their sales prices rose further, relatively weakening their market competitiveness. This widening relative cost gap shifts some demand, thereby increasing market demand for Country A manufacturers. Proposition 4 indicates that different tariff structures redistribute demand by altering price differentials between manufacturers in the two countries, thereby guiding consumers' choices among substitute products.

Under different tariff structures, manufacturers in Country B experience distinct variations in cost differentials and competitive positions, potentially altering the direction and magnitude of shifts in market demand. Proposition 5 is derived from a comparative analysis of equilibrium demand for Country B manufacturers across four scenarios.

Proposition 5.（1）Comparing the tariff-free scenario with Country A imposing unilateral tariffs on Country B, Country B's manufacturers experience higher market demand under Country A's unilateral tariffs than in the tariff-free scenario, i.e.,$q_B^{NN} < q_B^{TN}$;（2）When raw material costs satisfy $c_7 < c < c_8$and competition intensity among manufacturers satisfies$0 < \lambda < \lambda_3$,the market demand for Country B's manufacturers in the tariff-free scenario exceeds that under Country B's unilateral tariff on Country A, i.e.,$q_B^{NN} > q_B^{NT}$;（3）When raw material costs satisfy$c_9 < c < c_8$, the market demand for Country B manufacturers under Country A's unilateral tariff scenario exceeds that under the bilateral tariff scenario, i.e.,$q_B^{TN} > q_B^{TT}$.

Proposition 5 compares the equilibrium demand of Country B's manufacturers under different tariff structures, with the variation essentially stemming from tariffs' impact on relative costs and equilibrium price structures. Since products from Countries A and B are substitutes in Country A's market, any adjustment in either party's costs or prices will affect the other party's demand share through consumer substitution behavior. In the comparison between zero tariffs and unilateral tariffs imposed by Country A, tariffs increase Country B manufacturers' sales costs, prompting them to adjust pricing. Consequently, Country B manufacturers experience higher demand under Country A's unilateral tariff scenario. In contrast, when comparing zero tariffs with unilateral tariffs imposed by Country B, tariffs elevate Country B manufacturers' marginal costs by increasing their raw material procurement expenses. This price disadvantage becomes more pronounced when competitive intensity is low. A bilateral tariff imposes cost pressures on Country B manufacturers for both intermediate goods and final products simultaneously. Their equilibrium price is relatively higher, resulting in lower market demand compared to the scenario with a unilateral tariff imposed by Country A. Thus, tariff retaliation fails to improve Country B manufacturers' competitive position in the opposing market. Instead, by increasing their own input costs, it intensifies the adverse impact on demand. This outcome demonstrates that within supply chain structures characterized by cross-border intermediate goods dependency, retaliatory tariffs may impose counterproductive constraints on enterprises, thereby exacerbating demand contraction and market share decline.

4.4. The equilibrate selection of manufacturers and suppliers

4.4.1. Equilibrium analysis of manufacturers

To characterize the direct impact of Country A's unilateral tariff policy on Country B's manufacturers, this section first compares the equilibrium profits of Country B's manufacturers under the tariff-free scenario versus the scenario with Country A's unilateral tariff, as shown in proposition 6.

Proposition 6. When raw material costs are in the lower range, i.e.,$0 < c < c_{10}$, under the scenario where Country A imposes unilateral tariffs on Country B, the equilibrium profit of Country B's manufacturers is higher than in the tariff-free scenario, i.e.,$\pi_{MB}^{TN} > \pi_{MB}^{NN}$.

Proposition 6 demonstrates that under certain cost conditions, Country A's imposition of import tariffs does not necessarily compress the profit margins of Country B's manufacturers. This is because when raw material costs are low, Country B's manufacturers possess strong cost absorption capacity. Although tariffs increase their unit sales costs for entering Country A's market, enterprises can partially shift the cost pressure by adjusting sales prices. Simultaneously, tariffs alter the price interaction between manufacturers in both countries, adjusting the market price structure. Within this cost range, the profit per unit gained from price adjustments outweighs the losses from reduced demand, ultimately increasing overall profit levels.

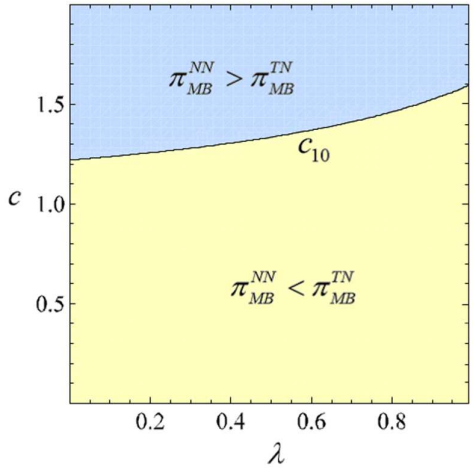

Fig. 2. Comparison of Country B Manufacturers' Profits Under Tariff-Free and Unilateral Tariff Scenarios by Country A（$r_A = 0.3$）

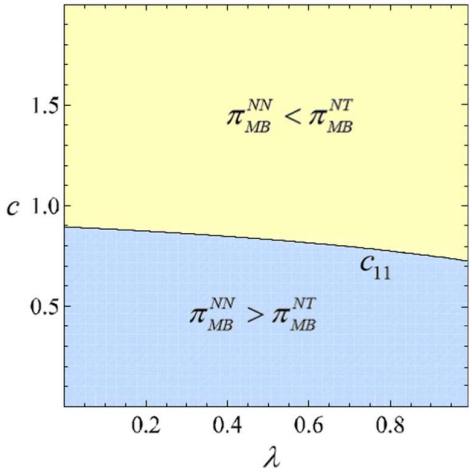

Fig. 3. Comparison of Country B Manufacturers' Profits Under Tariff-Free and One-Way Tariff Scenarios

Under Country B's one-way tariff scenario, the tariff does not affect the final product but is directly imposed on the raw materials procured by Country B manufacturers from Country A. Whether this tariff can reduce Country B manufacturers' profits depends on whether Country A suppliers partially absorb the tariff shock by lowering wholesale prices. By comparing the profits of Country B manufacturers under tariff-free conditions versus the unilateral tariff scenario, we analyze whether Country B manufacturers truly bear the tariff burden. Based on this analysis, we arrive at proposition 7.

Proposition 7. When raw material costs are in the lower range, i.e.,$0 < c < c_{11}$,the equilibrium profit of Country B's manufacturers under a unilateral import tariff scenario is lower than under a tariff-free scenario, i.e.,$\pi_{MB}^{NT} < \pi_{MB}^{NN}$.

Proposition 7 indicates that under a scenario where Country B imposes one-way tariffs, if upstream suppliers fail to sufficiently reduce wholesale prices to absorb the tariff shock, the tariff cost will primarily be passed on to Country B manufacturers, thereby compressing their profit margins. This occurs because when Country B imposes import tariffs on suppliers from Country A, the marginal procurement costs for Country B manufacturers increase. However, to maintain sales volume to Country B manufacturers, Country A suppliers may choose to lower wholesale prices to partially absorb the tariff shock. Yet if raw material costs are low, suppliers' room for price reductions is limited, preventing them from fully offsetting the incremental costs from tariffs. Consequently, Country B manufacturers bear the bulk of the tariff burden. The cost increase squeezes their profit margins. Even if they can partially pass on costs through price increases in competitive markets, revenue gains from price hikes are insufficient to offset lost sales volume and increased costs due to demand elasticity constraints and competitive pressure from Country A manufacturers. This ultimately leads to declining profits. This finding reveals that in cross-border supply chains, the cost of intermediate goods tariffs is borne more by importing country manufacturers than by upstream exporters, exhibiting a characteristic of “reverse transmission” of tariff burdens.

In a scenario where Country A has imposed tariffs on final products from Country B, the profits of Country B's manufacturers have already been affected by rising costs. If Country B then imposes retaliatory tariffs on imported raw materials, this creates a situation of overlapping tariffs in both directions. Comparing the equilibrium profits of Country B's manufacturers under Country A's unilateral tariff scenario versus the bilateral tariff scenario yields proposition 8.

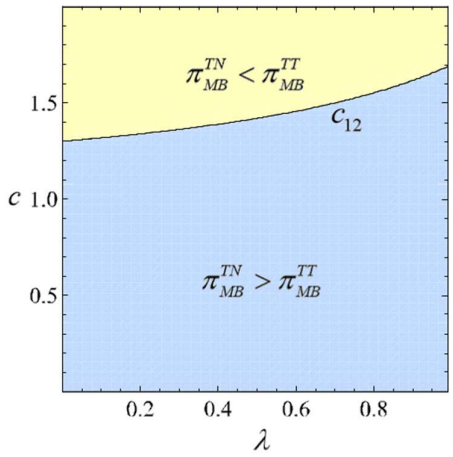

Fig. 4. Comparison of Country B Manufacturers' Profits Under Unilateral and Bilateral Tariff Scenarios in Country A（$r_A = 0.3, r_B = 0.3$）

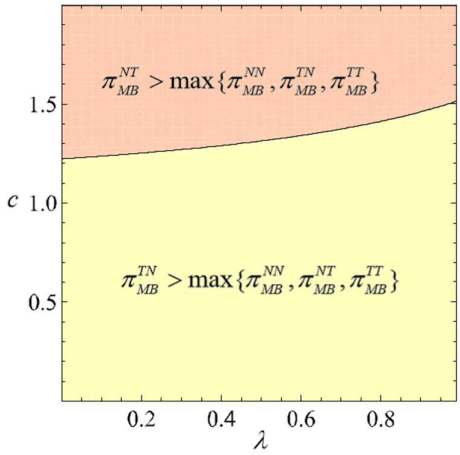

Fig. 5. Comparison of Country B Manufacturers' Profits Under Tariff-Free, Unilateral Tariff, and Bilateral Tariff Scenarios（$r_A = 0.3, r_B = 0.3$）

Proposition 8. When raw material costs are in the lower range, i.e.,$0 < c < c_{12}$, the equilibrium profit of Country B's manufacturers under Country A's unilateral tariff scenario exceeds that under the bilateral tariff scenario, i.e.,$\pi_{MB}^{TN} > \pi_{MB}^{TT}$.

Proposition 8 indicates that when Country A imposes tariffs on final products from Country B, further retaliatory tariffs by Country B on imported raw materials do not improve the profitability of Country B's manufacturers. Instead, it reduces their profit levels below those under a unilateral tariff scenario. This occurs because reciprocal tariffs subject Country B's manufacturers to dual cost pressures, tariffs on both final and intermediate goods, significantly increasing marginal costs. Although upstream suppliers may adjust wholesale prices, their room for price reductions is limited within the range of lower raw material costs, failing to effectively offset the cost shock from the cumulative tariffs. The substantial cost increase compresses Country B manufacturers' profit margins. Even attempts to pass on costs through price hikes in competitive markets face constraints from demand elasticity and competitive pressure from Country A manufacturers, making full cost recovery difficult. Ultimately, profits fall below the level observed under unilateral tariffs. This finding reveals that tit-for-tat tariff retaliation in trade wars may impose counterproductive constraints on domestic firms, exacerbating their competitive disadvantages in the market.

Building upon the preceding comparison of tariff-free, single-directional tariff, and double-directional tariff scenarios, it is necessary to further comprehensively examine the optimal profit performance of Country B's manufacturers under different tariff structures, as illustrated in proposition 9.

Proposition 9. When raw material costs are low and tariffs are equal between the two countries, Country A's unilateral tariff scenario is more advantageous for Country B's manufacturers. When raw material costs are high, Country B's unilateral tariff scenario is more advantageous for Country B's manufacturers.

Proposition 9 reveals that under symmetric tariffs, the optimal profit performance of Country B's manufacturers exhibits structural differences as raw material costs fluctuate. Within the range of lower raw material costs, Country B's manufacturers demonstrate strong cost absorption capacity. At this point, if Country A imposes tariffs on Country B's finished goods, the lower raw material costs provide them with pricing adjustment buffer space. Concurrently, while Country A manufacturers gain a relatively competitive advantage due to tariffs, their sales prices also rise, inadvertently creating room for Country B manufacturers to increase their prices and partially pass on the tariff burden. Consequently, Country B manufacturers achieve relatively higher profits under the TN scenario. When raw material costs are high, suppliers have greater scope for price reductions, significantly enhancing their ability to absorb tariffs and substantially alleviating cost pressures on Country B manufacturers. Concurrently, while Country A manufacturers gain cost advantages from lower wholesale prices, this does not fully translate into market dominance over Country B manufacturers. Instead, the easing of price competition maintains a relatively stable market structure, resulting in superior profit performance for Country B manufacturers under the NT scenario.

Notably, the scenario of reciprocal tariffs did not emerge as the optimal choice for manufacturers in Country B across either

raw material cost range. This indicates that tariff retaliation fails to improve their profit margins; instead, the cumulative cost effect places them in a more disadvantageous competitive position. This finding reveals that within cross-border supply chains, the actual impact of tariff policies depends not only on tariff rates but also on the complex interplay of cost structures, pricing responses, and market competition dynamics.

4.4.2. Equilibrium analysis of supplies

By comparing the profits of suppliers in Country A under scenarios of unilateral tariffs imposed by Country A versus unilateral tariffs imposed by Country B, analyze the patterns of profit shifts in upstream sectors resulting from differences in tariff application points, as illustrated in proposition 10.

Proposition 10. When raw material costs satisfy$0 < c < c_{13}$ or $c_{14} < c < c_{15}$, the profit of Country A's suppliers under Country A's unilateral tariff imposition exceeds that under Country B's unilateral tariff imposition, i.e.,$\pi_{sA}^{TN} > \pi_{sA}^{NT}$.

Proposition 10 analyzes how different tariff application points affect upstream supplier profits. When Country A imposes unilateral tariffs on final goods, tariffs indirectly enhance the bargaining power of Country A's suppliers over downstream buyers by weakening the market competitiveness of Country B's manufacturers. This allows suppliers to raise wholesale prices and benefits. Conversely, when Country B imposes unilateral tariffs on intermediate goods, tariffs directly increase export costs for Country A's suppliers. To maintain sales volume, suppliers must lower wholesale prices, resulting in direct profit compression. Although suppliers can partially absorb tariff shocks through price adjustments within specific cost ranges, tariffs directly applied to intermediate goods generally inflict more significant damage to supplier profits. This indicates that tariffs' impact on upstream enterprises depends on their transmission pathways within the supply chain: tariffs applied downstream may indirectly benefit suppliers through competitive effects, while those applied upstream directly erode their profits.

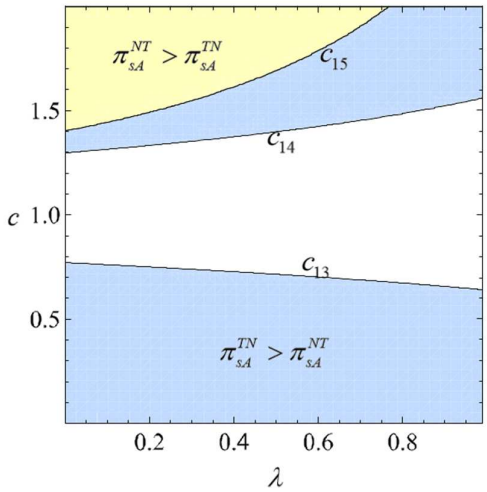

Fig. 6. Comparison of Supplier Profits in Country A Under Unilateral Tariff Scenarios in Country A and Country B （$r_A = 0.3, r_B = 0.3$）

5. Extension-asymmetric tariff scenarios

The preceding discussion examined the profit performance of supply chain members under various tariff scenarios based on symmetric tariff conditions. This section primarily analyzes how supply chain members adjust their strategic choices under asymmetric tariff conditions.

Under the assumption of symmetric tariffs, Proposition 10 analyzes how the profits of suppliers in Country A change under two scenarios: when Country A imposes a unilateral tariff on final goods and when Country B imposes a unilateral tariff on intermediate goods. Figure 7 further extends the analysis to asymmetric tariff scenarios, examining how the comparative profits of suppliers in Country A shift when the tariff rates between the two countries are inconsistent. Figure 7(a) shows that when Country A imposes a higher tariff on final goods from Country B than Country B imposes on intermediate goods from Country A, the range of raw material costs where $\pi_{sA}^{NT} > \pi_{sA}^{TN}$ expands compared to the symmetric tariff scenario depicted in Figure 6. This occurs because while the higher r_A enhances the competitiveness of Country A's manufacturers in the market, it also pushes up their selling prices, thereby suppressing the scale of their demand for upstream raw materials. This, in turn, reduces the profit margin available to suppliers in the TN scenario through price increases. Conversely, the relatively lower r_B exerts a smaller direct impact on suppliers' export costs. In the NT scenario, suppliers can maintain sales volume by moderately lowering prices, keeping the extent of profit erosion relatively manageable. Figure 7(b) illustrates that when Country B's tariff exceeds Country A's tariff, the interval where $\pi_{sA}^{NT} > \pi_{sA}^{TN}$ significantly narrows. At this point, the higher intermediate goods tariff r_B directly increases export costs for Country A's suppliers, forcing them to substantially reduce

wholesale prices to maintain sales volume to Country B's manufacturers, thereby significantly compressing profit margins. However, the lower final goods tariff r_A has limited stimulating effects on downstream demand, making it difficult to compensate for suppliers' profit losses under the TN scenario through expanded demand. In summary, when final goods tariffs are relatively high, Country B's unilateral tariff scenario may become a relative advantage for suppliers. Conversely, when intermediate goods tariffs are relatively high, suppliers' profit disadvantages under Country B's unilateral tariff scenario become more pronounced.

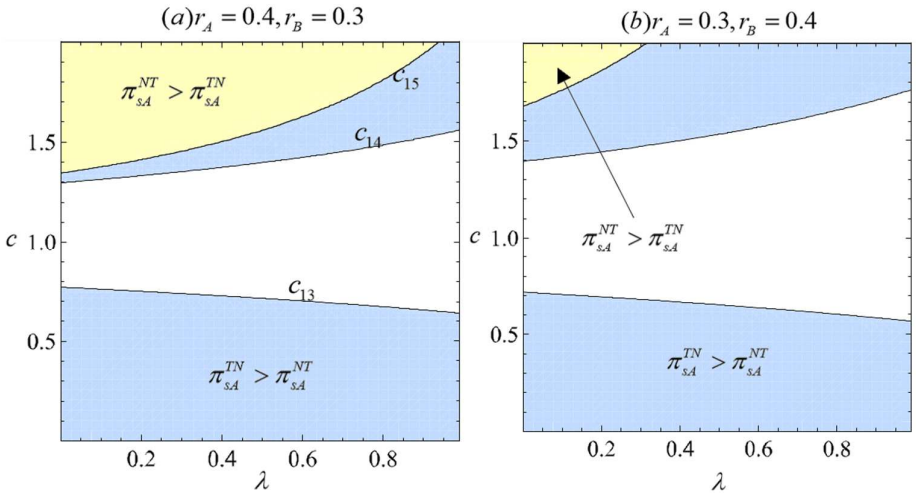

Fig. 7. Comparison of Supplier Profits in Country A Under Unilateral Tariff Scenarios in Country A and Country B

Proposition 11. Under asymmetric tariff conditions, the profit comparison for Country B's manufacturer across three scenarios, no tariffs, Country A imposing unilateral tariffs on final goods, and Country B imposing unilateral tariffs on intermediate goods, is as follows:（1）When $0 < c < c_{11}$, $\pi_{MB}^{TN} > \pi_{MB}^{NN} > \pi_{MB}^{NT}$;（2）When $c_{11} < c < c_{16}$, $\pi_{MB}^{TN} > \pi_{MB}^{NT} > \pi_{MB}^{NN}$;（3）When $c_{16} < c < c_{10}$, $\pi_{MB}^{NT} > \pi_{MB}^{TN} > \pi_{MB}^{NN}$;（4）When $c > c_{11}$, $\pi_{MB}^{NT} > \pi_{MB}^{NN} > \pi_{MB}^{TN}$.

Under conditions where Country A imposes higher tariffs on final goods from Country B than Country B imposes on intermediate goods from Country A, Country B's manufacturers achieve maximum profits in the TN scenario and minimum profits in the NT scenario when raw material costs are low. This occurs because lower raw material costs grant Country B manufacturers greater capacity to absorb Country A's tariffs, enabling them to partially pass on the tax burden through price increases. Conversely, Country B's tariffs directly inflate procurement costs, and with limited room for suppliers to reduce prices, profits suffer significantly. As raw material costs rise, Country B manufacturers maintain their profit advantage under the TN scenario. However, profits under the NT scenario gradually surpass those in the tariff-free scenario. This indicates that within the higher raw material cost range, suppliers partially absorb the tariff shock through price reductions, alleviating cost pressures on Country B manufacturers. When raw material costs are high, expanded supplier discounting capacity allows them to absorb Country B's tariff impact more fully. In the TN scenario, however, the combination of high Country A tariffs and elevated raw material costs severely compresses Country B manufacturers' profit margins. Consequently, Country B manufacturers' profits in the NT scenario surpass those in both the TN scenario and the tariff-free scenario, making it the optimal choice.

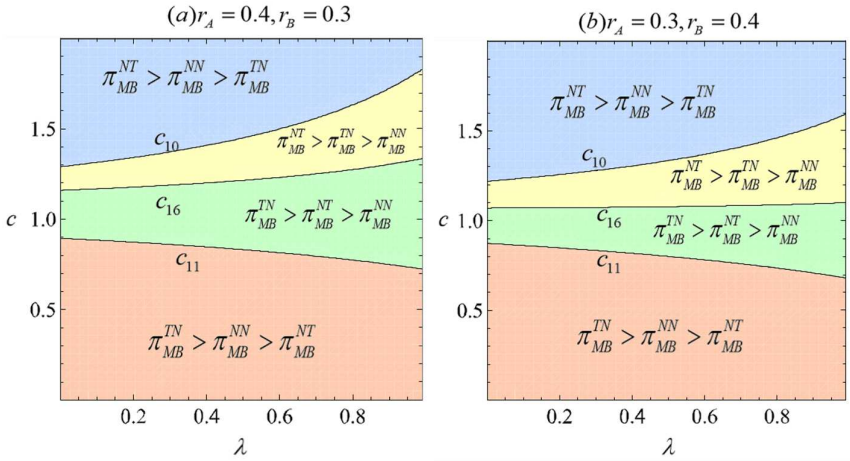

Fig. 8. Comparison of Country B Manufacturers' Profits Under Tariff-Free, Unilateral Tariff by Country A, and Unilateral Tariff by Country B Scenarios

Observing Fig. 8(b), we find that compared to Fig. 8(a), the blue region expands as $\pi_{MB}^{NT} > \pi_{MB}^{NN} > \pi_{MB}^{TN}$. This occurs because higher tariffs in Country B directly increase procurement costs for Country B manufacturers. Simultaneously, these tariffs compel Country A suppliers to significantly reduce wholesale prices to maintain sales volume. Conversely, lower tariffs in Country A exert relatively limited cost pressure on Country B manufacturers, thereby weakening the profit advantage in the TN scenario. Additionally, the green region ($\pi_{MB}^{TN} > \pi_{MB}^{NT} > \pi_{MB}^{NN}$) contracts compared to Fig. 8(a), further illustrating that higher tariffs in Country B enhance the NT scenario's advantage for Country B manufacturers.

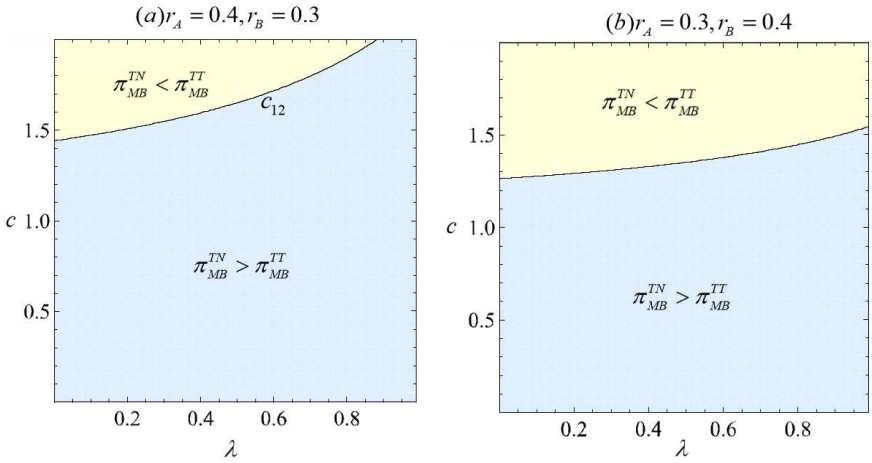

Fig. 9. Comparison of Country B Manufacturers' Profits Under Unilateral and Bilateral Tariff Scenarios in Country A

Fig. 9 extends the analysis of Proposition 8 to asymmetric tariff scenarios. Compared to symmetric tariffs (Figure 4), the region where$\pi_{MB}^{TN} > \pi_{MB}^{TT}$ expands significantly when Country A's tariff exceeds Country B's tariff. In this case, Country B's lower tariff implies relatively less intermediate goods cost pressure for Country B manufacturers under the TT scenario. However, under the TT scenario, Country B manufacturers bear the combined costs of both Country A's and Country B's tariffs, resulting in a significantly higher increase in marginal costs than under the TN scenario. Therefore, the TN scenario is preferable to the TT scenario. Figure 9(b) illustrates the opposite scenario: when raw material costs are high, suppliers have greater room to reduce prices, enhancing their ability to absorb tariffs. This results in the actual cost increase for Country B manufacturers under the TT scenario being lower than the tariff rate, thereby mitigating the extent of profit erosion. Concurrently, while lower tariffs in Country A exert limited cost pressure on Country B manufacturers under the TN scenario, they combine with higher tariffs in Country B under the TT scenario to create a cost-additive effect. This paradoxically reduces the relative disadvantage of the TT scenario within specific cost ranges, shrinking the region where $\pi_{MB}^{TN} > \pi_{MB}^{TT}$ and expanding the region where $\pi_{MB}^{TN} < \pi_{MB}^{TT}$.

It can be observed that when Country A imposes relatively higher tariffs, the advantageous range of unilateral tariffs expands, and the escalation of trade wars inflicts more significant additional damage on Country B's manufacturers. Conversely, when Country B imposes relatively higher tariffs, the relative disadvantage of bilateral tariffs diminishes, and under certain conditions, bilateral tariffs may even prove superior to unilateral tariffs.

6. Conclusion and managerial insights

6.1. Main findings

This paper constructs a three-tier cross-border supply chain game model involving suppliers from Country A, manufacturers from Country A, and manufacturers from Country B. It analyzes the optimal pricing decisions and equilibrium outcomes of supply chain members under tariff-free, unilateral tariff, and bilateral tariff scenarios. Furthermore, it explores the impact of asymmetric tariff structures on corporate strategy selection. Key findings include:

Tariffs influence pricing decisions of upstream and downstream enterprises through cost pass-through. When applied to final goods, tariffs raise the marginal cost of Country B manufacturers, leading to higher selling prices, while simultaneously strengthening the bargaining power of Country A suppliers and increasing wholesale prices. When applied to intermediate goods, tariffs increase procurement costs for Country B manufacturers, compelling Country A suppliers to lower wholesale prices to maintain sales volume. Under reciprocal tariffs, the cumulative cost effect causes wholesale prices to be positively influenced by Country A's tariffs and negatively impacted by Country B's tariffs. Consequently, the selling prices of manufacturers in both countries exhibit a non-monotonic pattern of first rising and then falling, reflecting the dynamic trade-off between cost-push inflation and demand contraction. The structural differences in demand allocation and profit changes stem from the distinct points at which tariffs take effect. Tariffs redistribute demand by altering prices for manufacturers in both countries, thereby guiding consumer choices. When applied to final goods, Country B manufacturers can pass on the tax

burden by raising prices when raw material costs are low, potentially achieving higher profits than in a tariff-free scenario. Conversely, when applied to intermediate goods, Country B manufacturers bear the primary tariff burden, experiencing lower profits than in a tariff-free scenario, a phenomenon known as “reverse pass-through”.

Unilateral tariffs and retaliatory reciprocal tariffs significantly impact corporate profitability. For manufacturers in Country B, lower raw material costs favor the unilateral tariff scenario in Country A, while higher costs make the unilateral tariff scenario in Country B more advantageous. Reciprocal tariffs remain suboptimal under all conditions, indicating that tariff retaliation fails to improve profit margins. Instead, the cumulative cost burden exacerbates competitive disadvantages. For suppliers, tariffs imposed on downstream entities can indirectly benefit upstream players through competitive effects, while tariffs imposed on upstream entities directly erode profits. Under asymmetric tariffs, the interaction between tariff intensity, costs, and competitive intensity further influences firms' optimal strategy choices.

6.2. Managerial insights

This study offers significant insights into multinational corporations' strategic decision-making under varying tariff environments. Companies must systematically evaluate the transmission effects of tariffs across upstream and downstream segments, rather than focusing solely on tariffs applied to final products. When tariffs target final goods, firms can pass on the tax burden through moderate price increases if raw material costs remain low. Conversely, when tariffs affect intermediate goods, proactive coordination with suppliers on price adjustments is essential to avoid becoming the primary bearer of tariff costs. Furthermore, companies must dynamically adjust strategies based on their cost structure and market competitiveness: in low-cost, less competitive environments, flexible pricing can shift pressure; in high-cost, highly competitive environments, efforts should focus on reducing procurement costs and enhancing operational efficiency to strengthen supply chain resilience.

For policymakers, this study demonstrates that tariff measures have significant supply chain linkage effects, with impacts often extending beyond the targeted segment to affect upstream and downstream enterprises. Therefore, trade policy formulation should emphasize coordination and systemic approaches to avoid the accumulation of costs and market distortions triggered by isolated protective tariffs. Retaliatory tariffs rarely achieve their intended goal of protecting domestic enterprises; instead, they may exacerbate competitive disadvantages through cost accumulation. It is recommended to prioritize dialogue, consultation, and multilateral coordination mechanisms. Concurrently, more structural policy tools, such as tariff quotas and product exemption lists, should be considered. These should be synergized with policies promoting innovation incentives and industrial chain upgrading to enhance domestic industrial competitiveness through appropriate protection, thereby boosting overall supply chain efficiency and stability.

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Appendix:

Proof of Lemma 1 Solve$\frac{\partial \pi_{MA}^N}{\partial q_A^N} = 0, \frac{\partial \pi_{MB}^N}{\partial q_B^N} = 0$yields$q_A^N = \frac{1}{2}(a - w_A^N - q_B^N \lambda), q_B^N = \frac{1}{2}(a - w_A^N - q_A^N \lambda)$, Combining these two equations yields$q_A^N = \frac{a - w_A^N}{2+\lambda}, q_B^N = \frac{a - w_A^N}{2+\lambda}$, Substituting these into $\pi_{sA}^N = (w_A^N - c)q_A^N + (w_A^N - c)q_B^N$, solving $\frac{\partial \pi_{sA}^N}{\partial w_A^N} = 0$yields

the equilibrium wholesale price $w_A^N = \frac{a+c}{2}$. Solve the expressions for demand, sales price, and profit by substituting the equilibrium wholesale price to obtain$q_A^N, q_B^N, p_A^N, p_B^N, \pi_{sA}^N, \pi_{MA}^N, \pi_{MB}^N$.

The proofs of Lemmas 2, 3, and 4 follow the same procedure as that of Lemma 1 and are therefore omitted.

Proof of Corollary 1 Solve $\frac{\partial w_A^{TN}}{\partial r_A} = \frac{a}{(2+r_A)^2} > 0$; solve $\frac{\partial p_A^{TN}}{\partial r_A} = \frac{\frac{c\lambda}{(1+r_A)^2} + \frac{2a(-2+\lambda+\lambda^2)}{(2+r_A)^2}}{2(-4+\lambda^2)}$, set $\frac{\partial p_A^{TN}}{\partial r_A} = 0$,yielding $r_{A1} = \frac{\sqrt{2}\sqrt{-ac\lambda(-2+\lambda+\lambda^2)} - 2c\lambda - 2a(-2+\lambda+\lambda^2)}{c\lambda + 2a(-2+\lambda+\lambda^2)}$,when $r_{A1} < r_A < 1$, $\frac{\partial p_A^{TN}}{\partial r_A} > 0$; solve $\frac{\partial p_B^{TN}}{\partial r_A} = \frac{\frac{c(-2+\lambda^2)}{(1+r_A)^2} + \frac{2a(-2+\lambda+\lambda^2)}{(2+r_A)^2}}{2(\lambda^2-4)} < 0$; solve $\frac{\partial q_A^{TN}}{\partial r_A} = \frac{\frac{c\lambda}{(1+r_A)^2} + \frac{2a(2+\lambda)}{(2+r_A)^2}}{2(-4+\lambda^2)} < 0; \frac{\partial q_B^{TN}}{\partial r_A} = \frac{\frac{c}{(1+r_A)^2} + \frac{a(2+\lambda)}{(2+r_A)^2}}{4-\lambda^2} > 0;$ solve $\frac{\partial \pi_{sA}^{TN}}{\partial r_A} = \frac{4a^2(1+r_A)^2 - c^2(2+r_A)^2}{4(1+r_A)^2(2+r_A)^2(2+\lambda)} > 0; \frac{\partial \pi_{MA}^{TN}}{\partial r_A} = \frac{\left(c(2+r_A)^2\lambda + 2a(1+r_A)^2(2+\lambda)\right)\left(c(2+r_A)(2+2r_A-\lambda) + 2a(1+r_A)(-2+\lambda+r_A\lambda)\right)}{2(1+r_A)^3(2+r_A)^3(-4+\lambda^2)^2}$,set $\frac{\partial \pi_{MA}^{TN}}{\partial r_A} = 0$ yielding $r_{A2} = \frac{c(-6+\lambda) - 4a(-1+\lambda) + \sqrt{16a^2 + c^2(2+\lambda)^2 + 8ac(-2+\lambda+\lambda^2)}}{4(c+a\lambda)}$,when $r_{A2} < r_A < 1$, $\frac{\partial \pi_{MA}^{TN}}{\partial r_A} > 0; \frac{\partial \pi_{MB}^{TN}}{\partial r_A} = \frac{\left(2a(1+r_A)(2+2r_A-\lambda) + c(2+r_A)(-2+\lambda+r_A\lambda)\right)\left(c(2+r_A)^2(2+\lambda+r_A\lambda) + 2a(1+r_A)\left(8+r_A(10+2r_A+\lambda)\right)\right)}{4(1+r_A)^2(2+r_A)^3(-4+\lambda^2)^2} > 0.$

The proofs for Corollaries 2 and 3 follow the same procedure as that for Corollary 1 and are therefore omitted.

The threshold in Corollary 2 is$r_{B1} = \frac{\sqrt{2-\lambda} + (-2+\lambda)\lambda}{1+\lambda-\lambda^2}, r_{B2} = -\frac{a(2-3\lambda) + c(-6+\lambda) + \sqrt{(2+\lambda)(2(-7a^2+10ac+c^2) + (-3a+c)^2\lambda)}}{4(a-c)}$.

The threshold in Corollary 3 is

$r_{A2} = \frac{2c(-2+\lambda)\lambda - a(2+rB)(1+rB-\lambda)\left(-4+\lambda^2\right) + crB\left(4+(1+rB-\lambda)\lambda^2\right) - \sqrt{-c(1+rB)^2(1+rB-\lambda)\lambda(-4+\lambda^2)\left(a(2+rB)(2+2rB-\lambda) + crB(2+\lambda)\right)}}{-c(-2+\lambda)\lambda + a(2+rB)(1+rB-\lambda)(-4+\lambda^2) + crB\left(-4+\lambda(-2+\lambda+\lambda^2)\right)}$,

$r_{B3} = \frac{-a(1+rA)(2+\lambda)(-4-4rA+2\lambda+3rA\lambda) + \sqrt{(1+rA)^2(-4+\lambda^2)\left(c^2(2+rA)(2+\lambda) + a^2(1+rA)(2+rA)(2+\lambda) + ac(8(1+rA)+(2+rA)^2\lambda)\right)\left(-2+rA(-2+\lambda^2)\right)} - c(2+rA)\left(-4+\lambda^2+2rA(-2+\right.}{-4(1+rA)(a+c+arA) - 2(a+c)(1+rA)\lambda + rA(a+c+arA)\lambda^2}$

.

Proof of Proposition 1 Solve $w_A^{NN} - w_A^{TN} = -\frac{ar_A}{4+2r_A} < 0$,hence $w_A^{NN} < w_A^{TN}$;solve $w_A^{NN} - w_A^{NT} = \frac{(a+c)r_B(2+2r_B-\lambda)}{4(2+2r_B+rB^2-(1+r_B)\lambda)} > 0$,hence $w_A^{NN} > w_A^{NT}$.

Solve $w_A^{NN} - w_A^{TT} = \frac{1}{2}\left(a + c - \frac{(a(1+r_A)(2+r_B)+c(2+r_A+r_B))(-2+\lambda)}{-2(2+r_A+r_B(2+r_B))+(2+r_A)(1+r_B)\lambda}\right)$,setting $w_A^{NN} - w_A^{TT} = 0$ yields $c_1 = \frac{a(r_A-r_B)(2+2r_B-\lambda)}{2r_B(1+r_B)-(1+r_A)r_B\lambda}$,when $c_1 < c$, $w_A^{TT} < w_A^{NN}$; solve $w_A^{TN} - w_A^{TT} = \frac{c}{2} + \frac{a(1+r_A)}{2+r_A} - \frac{(a(1+r_A)(2+r_B)+c(2+r_A+r_B))(-2+\lambda)}{-4(2+r_A+r_B(2+r_B))+2(2+r_A)(1+r_B)\lambda}$,setting$w_A^{TN} - w_A^{TT} = 0$ yields$c_2 = \frac{4a+2ar_A-2ar_A^2+4ar_B+4ar_Ar_B-2a\lambda-3ar_A\lambda-ar_A^2\lambda}{-4-2r_A-4r_B-2rAr_B+2\lambda+3r_A\lambda+r_A^2\lambda}$,when $c_2 < c$, $w_A^{TN} < w_A^{TT}$.

Proof of Proposition 2 Solve $p_A^{NN} - p_A^{TN} = -\frac{r_A\left(c(2+r_A)\lambda + a(1+r_A)(-2+\lambda+\lambda^2)\right)}{2(1+r_A)(2+r_A)(-2+\lambda)(2+\lambda)}$,setting $p_A^{NN} - p_A^{TN} = 0$ yields $c_3 = \frac{2a+2ar_A-a\lambda-ar_A\lambda-a\lambda^2-ar_A\lambda^2}{2\lambda+r_A\lambda}$,where $0 < c < c_3$ implies $p_A^{NN} < p_A^{TN}$; Under symmetric tariffs i.e., $r_A = r_B$,comparep_A^{TN} and p_A^{TT},solve $p_A^{TN} - p_A^{TT} = c + a(1 + \frac{r_A\lambda}{r_A(-2+\lambda^2)-2+\lambda+\lambda^2})$>0,thus $p_A^{TN} > p_A^{TT}$.

The proof process for Proposition 3 is identical to that of Proposition 2 and will therefore not be repeated here.

The threshold in Proposition 3 is $\lambda_1 = \frac{\sqrt{9a^2(1+r_A)^2+16ac(1+r_A)(2+r_A)+8c^2(2+r_A)^2} - a(1+r_A)}{2(a+2c+(a+c)r_A)}, \lambda_2 = \frac{1}{1+r_B}, c_4 = -\frac{a(1+r_A)(2+\lambda)\left(4+2r_A(3+r_B)+(1+r_A)(-6+r_A-4r_B)\lambda+(2+r_A)(1+r_B)\lambda^2\right)}{(2+r_A)(4(1+r_A)-2(2+r_A)(1+r_B)\lambda+(-1+r_A^2)\lambda^2+(1+r_B)\lambda^3}$.

Proof of Proposition 4 To ensure $q_A^{TN} > 0$,solving yields $c_5 < c < c_6$,where $c_5 = \frac{2a-2ar_A^2}{2+5r_A+2r_A^2}, c_6 = \frac{4a+4ar_A-2a\lambda-4ar_A\lambda-2ar_A^2\lambda}{4+6r_A+2r_A^2-2\lambda-r_A\lambda}$,at this point, $q_A^{NN} > q_A^{TN}$ .Solve $q_A^{TN} - q_A^{TT} = \frac{r_B\left(\frac{a(1+r_A)\left(2(1+r_A)\left(r_A-2(1+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)}{(2+r_A)(-2+\lambda)} + \frac{c(-4(1+r_A)(1+r_B)+2r_A(1+r_A)\lambda+(1+r_B)\lambda^2)}{-4+\lambda^2}\right)}{2(1+r_A)\left(-2(2+r_A+r_B(2+r_B))+(2+r_A)(1+r_B)\lambda\right)}$,at the same time $r_A = r_B$,setting $q_A^{TN} - q_A^{TT} = 0$ yields $a_1 = -\frac{c(2+r_A)\left(-4(1+r_A)(1+r_B)+2r_A(1+r_A)\lambda+(1+r_B)\lambda^2\right)}{(1+r_A)(2+\lambda)\left(2(1+r_A)\left(r_A-2(1+r_B)\right)+(2+r_A)(1+r_B)\lambda\right)}$,when $a_1 < a \le 1, q_A^{TN} < q_A^{TT}$.

The proof process for Proposition 5 is identical to that of Proposition 4, so it will not be repeated here.

The threshold in Proposition 5 is $c_7 = \frac{2a-ar_B+2ar_B^2}{2+5r_B+2r_B^2}, c_8 = \frac{4a+2ar_B+2ar_B^2-2a\lambda-3ar_B\lambda}{4+6r_B+2r_B^2-2\lambda-r_B\lambda}, \lambda_3 = \frac{4a-4c+2ar_B-6cr_B+2ar_B^2-2cr_B^2}{2a-2c+3ar_B-cr_B}, c_9 = -\frac{a(1+r_A)(2+\lambda)(-4-2r_A(3+r_B)+(1+r_A)(2+r_A)\lambda)}{(2+r_A)(-4(1+r_A)-2rA(1+r_B)\lambda+(1+r_A)^2\lambda^2)}$.

Proof of Proposition 6 Solve $\pi_{MB}^{TN} - \pi_{MB}^{NN} = \frac{1}{4}\left(-\frac{(a-c)^2}{(2+\lambda)^2} + \frac{\left(2a(1+r_A)(2+2r_A-\lambda)+c(2+r_A)(-2+\lambda+r_A\lambda)\right)^2}{(1+r_A)(2+r_A)^2(-4+\lambda^2)^2}\right)$,setting$\pi_{MB}^{TN} - \pi_{MB}^{NN} =$

0yields$c_{10} = \frac{(1+rA)\left(arA(-4+(4+4rA-\lambda)\lambda)-(2+r_A)\left(-4+\lambda^2\right)^2\sqrt{\frac{a^2r_A^2\left(6+\lambda+r_A(4+\lambda)\right)^2}{(1+r_A)(2+r_A)^2(-2+\lambda)^2(2+\lambda)^4}}\right)}{rA(2+r_A)(4-(1+r_A)\lambda^2)}$,when $0 < c < c_{10}$, $\pi_{MB}^{TN} > \pi_{MB}^{NN}$.

The proofs for Propositions 7, 8, 9, 10, and 11 follow the same procedure as Proposition 6 and are therefore omitted.

The threshold for propositions is $c_{11} = \frac{a(8+r_B(6+4r_B-5\lambda)-4\lambda)}{8+r_B(10+4r_B-3\lambda)-4\lambda}$, $c_{12} = \frac{a(1+r_A)\left(4\left(8+4r_A(3+r_A)+6r_B+5r_Ar_B+(4+3r_A)r_B^2\right)-2\left(16(1+r_B)+(4+r_A)\left(r_B^2+r_A(4+3r_B)\right)\right)\lambda+(2+r_A)(4+(5+r_A)r_B)\lambda^2\right)}{(2+r_A)\left(8(2+r_A)+4(5+rA)r_B+8r_B^2-2\left(2r_A^2+2(2+r_B)^2+r_A(8+r_B(5+r_B))\right)\lambda+(1+r_A)(4+3r_B+r_A(2+r_B))\lambda^2\right)}$, $c_{13} = \frac{4\sqrt{a^2r_B^2(2+\lambda)\left(2+2r_B+r_B^2-(1+r_B)\lambda\right)}-a\left(8-4\lambda+r_B\left(8-4\lambda+r_B(6+\lambda)\right)\right)}{(2+r_B)^2(-2+\lambda)}$, $c_{14} = \frac{4\sqrt{a^2rB^2(2+\lambda)\left(2+2r_B+r_B^2-(1+r_B)\lambda\right)}+a\left(8-4\lambda+r_B\left(8-4\lambda+r_B(6+\lambda)\right)\right)}{(2+r_B)^2(2-\lambda)}$, $c_{15} = -\frac{a(1+r_A)r_B^2(2+\lambda)+\sqrt{2}\sqrt{-\frac{a^2r_A^2(1+r_A)(2+r_B)^2(-2+\lambda)(2+2r_B+r_B^2-(1+r_B)\lambda)}{2+r_A}}}{-4r_A(1+r_B)+r_A(2+r_B(2+r_B))\lambda+r_B^2(2+\lambda)}$,solving $\pi_{MB}^{TN} = \pi_{MB}^{NT}$ yields c_{16}.

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