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Research Article

Green Product Pricing and Purchasing Strategies in a Two-Period Supply Chain considering Altruistic Preferences

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With improvements in consumers' environmental awareness and the promulgation of environmental regulations, an increasing number of companies are beginning to pay attention to green product design, pricing, and purchasing strategies. However, due to demand fluctuations and cost changes brought about by green product design and manufacturing, understanding corporate behavior preferences and constructing non-single-period pricing and procurement strategies can profoundly affect long-term cooperation among green supply chain members. This paper constructs six scenarios in which decision-makers have altruistic preferences simultaneously or separately and whether the retailer adopts strategic inventory. In addition, the impact of altruistic preferences and strategic inventory on the decision-making and profits of the two-period supply chain for marginal cost-intensive green products (MIGPs) are analyzed. The results show that altruistic preferences and purchasing strategies do not affect MIGPs' greening levels. Besides, the retailer's strategic inventory is still an effective bargaining tool but is not necessarily beneficial to profits. Noteworthy, when deciders exhibit altruism simultaneously or alone, the effects on certain decisions and strategic inventory range are significantly different. Finally, the retailer's altruistic preference may not affect the green supply chain's profits, but the manufacturer's altruism improves total profits.

1. Introduction

An increasing number of manufacturers have begun to devote themselves to the production of green products and the construction of green supply chains, which are affected by many aspects. First, more stringent environmental laws and regulations have been issued worldwide, and environmental protection supervision has been strengthened in various countries [1–4]. Besides, some governments and institutions also provide subsidy policies or incentive mechanisms for green manufacturers [5]. Second, with energy-saving appliances, green cars, biodegradable films, less polluting cleaners, energy star certified home appliances (Best Buy), and other innovative eco-friendly products gradually being recognized, consumers agree to pay higher premiums for innovative green products [6, 7]. Third, enterprises can create a corporate image of social responsibility by providing eco-friendly products [8]. As an essential facet of manufacturers' green production, green product design has received increasing attention and investment. For example, Apple, Mitsubishi Electric, and General Electric have launched various design plans to reduce energy consumption and increase renewable utilization [3, 9]. Toyota has designed a hybrid vehicle (Prius) that can not only reduce exhaust pollution but also save fuel [10].

For retailers that face rising wholesale prices and changing demand in manufacturer-led green supply chains, various purchasing strategies may bring differentiated profits. Among these strategies, strategic inventory, as an important tool that retailers use to bargain, has attracted more attention [11]. With strategic inventory, retailers buy commodities needed in the current period and hold them until the next period to secure lower wholesale prices [12]. CELSA, a Spanish iron and steel company, stacks scrap metal outside the plant as a useful negotiation tool to force dealers to reduce prices [13]. It is noteworthy that much of the previous literature on strategic inventory or green product design assumes that members in supply chains are entirely rational. In real life, with the development of globalization and the aggravation of supply chain competition and cooperation, many decision-makers have altruistic preferences to improve whole supply chains. That is, decision-makers with altruistic preference consider not only their own interests but also the impacts on others. Altruistic members seek to help others promote social welfare [14]. For example, Toyota provides technical and management support for its suppliers to improve productivity. General Motors helps its suppliers upgrade their technologies.

Therefore, this paper constructs two-period game models for MIGPs to consider the complex impacts of altruistic preferences and strategic inventory on the decision-making and profits of green supply chains. In addition, optimal design, pricing, and purchasing strategies for MIGPs under six scenarios are compared and analyzed. The present study mainly investigates the following issues: (1) do changes in altruism and purchasing strategies affect the greening level (GL)? (2) Does holding strategic inventory have different impacts on supply chain members in different scenarios? (3) How do the altruistic preferences of different members affect the range of strategic inventory that the retailer can hold, and how do these influence decisions and profits? (4) Are there differences in the impacts of decision-makers' altruism when present simultaneously or alone? (5) Which scenario is more beneficial to the whole green supply chain? To answer these questions, this paper constructs six scenarios including a rational manufacturer and altruistic retailer with strategic inventory (RAI), a rational manufacturer and altruistic retailer without strategic inventory (RAN), an altruistic manufacturer and rational retailer with strategic inventory (ARI), an altruistic manufacturer and rational retailer who purchases in every period (ARN), both members are altruistic and holding strategic inventory (AAI), and both members are altruistic and without strategic inventory (AAN).

First, for the differentiation scenarios, the retailer holding strategic inventory does not necessarily choose to order more goods in period one. Holding strategic inventory may not be conducive to improving the retailer's and manufacturer's profits. Second, the manufacturer's altruistic preference narrows the range of strategic inventory that the retailer can hold, while the range may not be affected by the retailer's altruistic preference. Third, strategic inventory and altruistic preference do not affect the GL of MIGPs. Interestingly, the influence of the retailer's altruism on decisions is impacted by whether the manufacturer has altruistic preferences. Finally, the retailer's altruism may not affect the green supply chain's profits, while the manufacturer's altruistic preference improves total profits.

The rest of this article is organized as follows. Section 2 presents a review of the relevant literature and compares the past work to the present paper. Mathematical notations and basic assumptions are provided in Section 3. Section 4 describes the six scenarios conducted and builds relevant models: AAI, AAN, ARI, ARN, RAI, and RAN. Then, upon comparing the calculation results, the effects of the decision-maker's altruism and strategic inventory are further discussed in Section 5. Section 6 summarizes the paper.

2. Literature Review

This paper focuses on marginal cost-intensive green products (MIGPs), constructs two-period game models for six scenarios, explores the influence of altruism on retailers' purchasing strategies, and analyses the complex effect of altruistic preference and strategic inventory on the design and pricing of green supply chain members. The research related to this study is mainly focused on three areas: green product design, strategic inventory, and altruistic preference.

2.1. Green Product Design. To achieve better economic performance, members of the green supply chain pay close attention to the R&D and manufacturing of products [15–18]. Similarly, Inman and Green [19] and Mao and Wang [20] also proposed that green manufacturing requires manufacturers to regularly upgrade production facilities and production technologies. Therefore, it is essential to make targeted production and pricing decisions in the face of differentiated products. For example, the design of high-speed bullet trains and biodegradable lubricants requires considerable research and development investment. However, promoting paper straws instead of plastic straws, using waste aluminum in new electrical appliances, or installing catalytic converters in cars involves higher manufacturing costs [6]. According to differences in the characteristics of products in the design and production process, Zhu and He [21] divided green products into three types, including MIGPs, DIGPs (development-intensive green products), and MDIGPs (marginal and development-intensive green products). Li et al. [3] considered the influence of retailers' competition and fairness concerns on green product design. Most of the previous literature on green product design considers a single period, but Mondal and Giri [7] studied the GL and marketing effort in a two-period supply chain. Unlike the above work, this paper not only focuses on the impact of non-single-period purchase strategies for MIGPs but also considers behavior preferences.

2.2. Strategic Inventory. As supply chains are characterized by complexity and vulnerability, members usually implement a variety of strategies to enhance the stability and sustainability of systems [22, 23]. Inventory is an essential means to maintain supply chain stability and resist sudden risks. Based on the various purposes of holding inventory, it can be divided into safety inventory, specific inventory, cycle inventory, etc. Among them, strategic inventory as an effective tool to enhance the buyer's bargaining power has been widely concerned. Anand et al. [12] pointed out that retailers can achieve lower wholesale prices by using their inventory as a useful bargaining tool. Desai et al. [24] discussed long-term procurement by retailers used to promote manufacturers' price reduction and found that holding strategic inventory is beneficial to both manufacturers and retailers within a certain range. Arya and Mittendorf [25] studied that manufacturers give consumers direct rebates to influence retailers to hold strategic inventories. Interestingly, members of the supply chain can benefit from rebates. Mantin and Jiang [11] considered the quality deterioration of goods in the strategic inventory model and found deterioration may be salubrious for the supply chain. Guan et al. [26] studied the interactions between strategic inventory and the introduction of the direct selling channel. Roy et al. [27] discussed the influence of unobservable strategic inventory on decisions. Nielsen et al. [28] focused on the impact of government differentiated incentive policies on procurement strategies (such as strategic inventory) and the GL under the two kinds of game structures. However, in previous studies on strategic inventory, green supply chains are rarely considered, especially in terms of green product design. In addition, most strategic inventory research is based on the basic assumption of decision-maker rationality. The present study not only considers green products' strategic inventory but also introduces the effect of behavioral factors on the MIGPs' supply chain.

2.3. Altruistic Preference. Kahneman and Tversky [29] found systematic deviation between the actual decisions of decision-makers and the theory of neoclassical economics under some uncertain conditions. This kind of decision-making error is common in the research on actual scenarios and operation management. Therefore, behavior operation management has been widely concerned in management research focused on under practice and theory.

Loch and Wu [30] organized an empirical study of "altruistic preference" behavior and found that most supply chain members with social responsibility concerns consider "profit transfer" as a means to improve their reputation. The altruistic preference can effectively promote the coordination and equilibrium of the overall revenue distribution of the supply chain, so it has received increasing attention [31, 32]. According to the number of subjects exhibiting altruism, the related literature can focus on two subjects. (1) Single altruistic decision-maker: Wang et al. [33] studied the effects of government subsidies and the remanufacturer's altruistic preferences on decisions made within a low-carbon supply chain. Wang et al. [34] showed that the retailer's altruistic preference could help increase the small and medium-sized manufacturer's profits and system efficiency. (2) Multiple altruistic decision-makers: Du et al. [35] built different scenarios involving decision-makers with altruistic preferences either simultaneously or alone. Considering the complex relationships between dual channels, the authors studied decision-making and coordination problems considering altruistic preferences. Xu and Wang [36] also discussed related issues affecting dual channels based on altruistic preferences. Wan et al. [37] constructed a dual-channel hotel supply chain network equilibrium model and studied the impact of agents' altruistic preferences on decisions. While most of the previous literature has mainly analyzed the influence of altruistic preferences on decisions and revenue in a single-period supply chain, this paper considers a two-period supply chain for MIGPs, and the differentiated purchasing strategies are introduced.

From the above review of related studies, the main contributions of this paper are as follows. (1) Through the introduction of strategic inventory, this paper considers decision-makers' altruistic preferences simultaneously or alone in a two-period supply chain. (2) By comparing results in different scenarios, this paper analyzes the impact of altruistic preferences on the range of strategic inventory. (3) This paper discusses whether strategic inventory has a differential impact on the GL and pricing after introducing altruistic preferences. In a word, the complex impacts of procurement strategies and altruistic preferences on the non-single-period green supply chain are also further analyzed.

3. Notations and Assumptions

3.1. Notations. The variables used in this paper are shown in Table 1.

3.2. Basic Assumptions

(1) This paper adopts demand function $D = a - bp + ce$, where $a\,(a > 0)$ denotes market potential. $(b > 0)$ and $c\,(c > 0)$ represent the sensitivity of consumers to prices and GL, respectively [21, 38].

(2) Following [9, 21], γe^2 is used to represent the additional unit cost with GL for MIGPs.

(3) The cross-period decline in commodity value is neglected. Besides, the paper assumes that GL of products does not change over two periods. This assumption is also based on the fact that some manufacturers, such as Apple, do not upgrade their products in certain periods, during which retailers make multiple purchases [9].

(4) This paper assumes that all market information is public [39]. Besides, the altruistic preference information is persistent. When the retailer and manufacturer have altruistic preferences, the decision-makers maximize their utility as their only goal.

(5) This paper does not consider the basic unit production cost, channel operation cost, order cost, etc. [12].

4. Analysis of the Models

This paper creates six scenarios based on decision-makers' behavioral preferences and purchasing strategies (AAI, AAN, ARI, ARN, RAI, and RAN). For the sake of clarity and simplicity, "he" and "she" represent the manufacturer and the retailer, respectively.

4.1. Strategic Inventory Models with Both Decision-Makers' Altruistic Preferences. In this section, manufacturer-Stackelberg (MS) game models for a two-level and two-period supply chain are constructed for MIGPs, and decision-makers with altruistic preferences simultaneously are considered.

Table 1: Notations.

	Respectively
Supply chain	
a	The market size
b	The sensitivity of consumers to price
c	The sensitivity of consumers to the greening level
e	The greening level of products
θ_r	The altruistic preference of the retailer
θ_m	The altruistic preference of the manufacturer
γ	The investment sensitivity of the green manufacturer to MIGPs
h	The unit inventory holding cost
$\prod$	The total profit of the green supply chain
Manufacture	
w_t	The unit wholesale price in period t, $t = 1, 2$
$\prod_m$	The total profit of the manufacture
U_m	The utility of the manufacture
Retailer	
p_t	The unit selling price in period t, $t = 1, 2$
q_t	The selling quantity of the retailer in period t, $t = 1, 2$
Q_t	The ordering quantity of the retailer in period t, $t = 1, 2$
I	The quantity of items which carried over the period 1 to period 2
$\prod_r$	The total profit of the retailer
U_r	The utility of the retailer
Superscript	
xyz	The manufacturer's behavioral preference $x \in \{R, A\}$, where R represents rational, A represents altruistic the retailer's behavioural preference $y \in \{R, A\}$ whether to hold strategic inventory $z \in \{I, N\}$, I represents holding strategic inventory, N represents no strategic inventory. For example, "ARI" means an altruistic manufacturer and a rational retailer in a two-period supply chain for MIGPs, and the retailer holds strategic inventory.

In scenario AAI, the manufacturer determines the GL of products e^{AAI} and first-period wholesale price w_1^{AAI}, and then the retailer decides selling price p_1^{AAI}, order quantity Q_1^{AAI}, and inventory I^{MAAI}. In period 2, wholesale price w_2^{AAI} is set by the manufacturer, and the retailer chooses second-period selling price p_2^{AAI} and order quantity Q_2^{AAI}. The specific decision-making sequence is shown in Figure 1. In addition, the retailer does not hold too many items because the item's surplus value is zero at the end of period 2.

Therefore, the first-period order quantity is $Q_1^{AAI} = q_1^{AAI} + I^{AAI}$, and the second-period order quantity is $Q_2^{AAI} = q_2^{AAI} - I^{AAI}$. For Scenario AAI, the utility functions are as follows:

$$\max U_{r2}^{AAI} = p_2^{AAI}\left(a - bp_2^{AAI} + ce^{AAI}\right) - w_2^{AAI}\left(a - bp_2^{AAI} + ce^{AAI} - I^{AAI}\right) + \theta_r\left(w_2^{AAI} - \gamma e^{AAI^2}\right)\left(a - bp_2^{AAI} + ce^{AAI} - I^{AAI}\right), \tag{1}$$

$$\max U_{m2}^{AAI} = \left(w_2^{AAI} - \gamma e^{AAI^2}\right)\left(a - bp_2^{AAI} + ce^{AAI} - I^{AAI}\right) + \theta_m\left(p_2^{AAI}\left(a - bp_2^{AAI} + ce^{AAI}\right) - w_2^{AAI}\left(a - bp_2^{AAI} + ce^{AAI} - I^{AAI}\right)\right), \tag{2}$$

$$\begin{aligned}\max U_r^{AAI} = {} & \left(p_1^{AAI} - w_1^{AAI}\right)\left(a - bp_1^{AAI} + ce^{AAI}\right) - \left(w_1^{AAI} + h - w_2^{AAI}\right)I^{AAI} + \left(p_2^{AAI} - w_2^{AAI}\right)\left(a - bp_2^{AAI} + ce^{AAI}\right) \\ & + \theta_r\left(\begin{array}{c}\left(w_1^{AAI} - \gamma e^{AAI^2}\right) * \\ \left(a - bp_1^{AAI} + ce^{AAI} + I^{AAI}\right) + \left(w_2^{AAI} - \gamma e^{AAI^2}\right)\left(a - bp_2^{AAI} + ce^{AAI} - I^{AAI}\right)\end{array}\right),\end{aligned} \tag{3}$$

$$\begin{aligned}\max U_m^{AAI} = {} & \left(w_1^{AAI} - \gamma e^{AAI^2}\right)\left(a - bp_1^{AAI} + ce^{AAI} + I^{AAI}\right) + \left(w_2^{AAI} - \gamma e^{AAI^2}\right)\left(a - bp_2^{AAI} + ce^{AAI} - I^{AAI}\right) \\ & + \theta_m\left(\left(p_1^{AAI} - w_1^{AAI}\right) * \left(a - bp_1^{AAI} + ce^{AAI}\right) - \left(w_1^{AAI} + h - w_2^{AAI}\right)I^{AAI} + \left(p_2^{AAI} - w_2^{AAI}\right)\left(a - bp_2^{AAI} + ce^{AAI}\right)\right).\end{aligned} \tag{4}$$

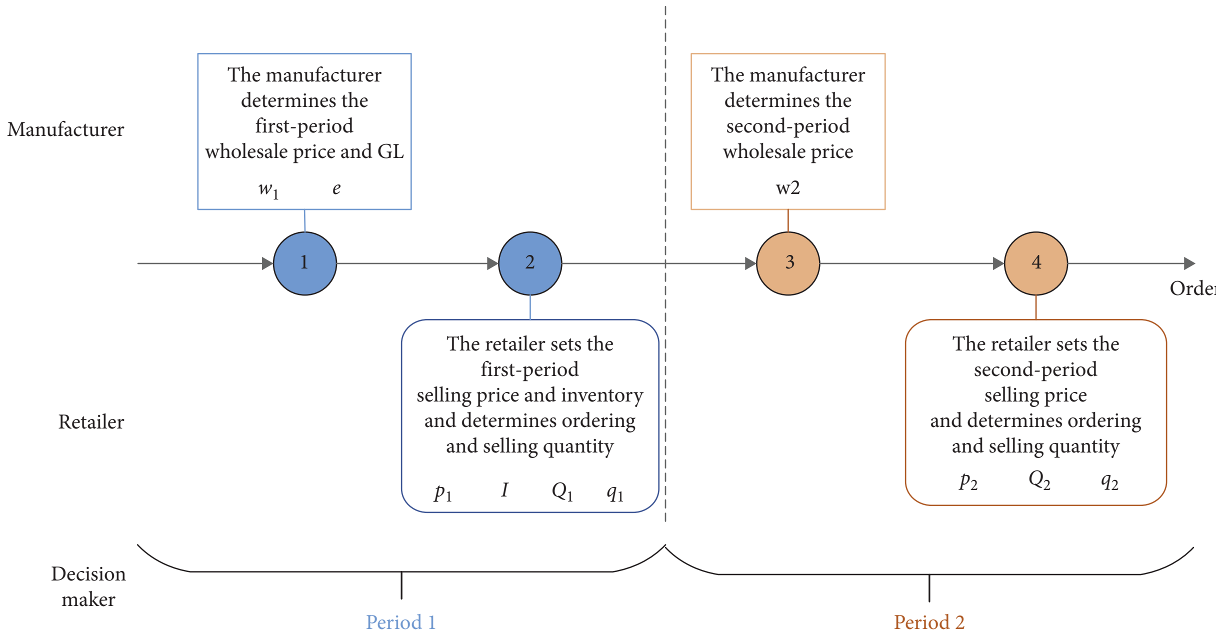


Figure 1: Decision process when the retailer holds strategic inventory.

When both decision-makers have altruistic preferences, formulas (1) and (3) are the retailer's utility functions. The manufacturer's utility functions are written as formulas (2) and (4). Backward induction is used to calculate and determine optimal decisions.

In scenario AAN, the manufacturer determines the GL of products e^{AAN} and first-period wholesale price w_1^{AAN}. Selling price p_1^{AAN}, ordering quantity Q_1^{AAN}, and selling quantity q_1^{AAN} are set by the retailer. The specific decision-making sequence is shown in Figure 2.

For a retailer without strategic inventory, the ordering quantity and selling quantity satisfy $Q_1^{AAN} = q_1^{AAN} = Q_2^{AAN} = q_2^{AAN}$, and the wholesale price satisfies $w_1^{AAN} = w_2^{AAN}$. For scenario AAN, the retailer's and manufacturer's utility functions are as follows:

$$\max U_{r1}^{AAN} = \left(p_1^{AAN} - w_1^{AAN}\right)\left(a - bp_1^{AAN} + ce^{AAN}\right) + \theta_r\left(w_1^{AAN} - \gamma e^{AAN^2}\right)\left(a - bp_1^{AAN} + ce^{AAN}\right), \quad (5)$$

$$\max U_{m1}^{AAN} = \left(w_1^{AAN} - \gamma e^{AAN^2}\right)\left(a - bp_1^{AAN} + ce^{AAN}\right) + \theta_m\left(p_1^{AAN} - w_1^{AAN}\right)\left(a - bp_1^{AAN} + ce^{AAN}\right). \quad (6)$$

Proposition 1. *For MIGPs, when supply chain members have altruistic preferences simultaneously, the optimal decisions are as shown in Table 2, and the proofs are shown in Appendix A.*

Proposition 1 The supply chain members' optimal decisions made in scenarios AAI and AAN. To ensure that the decision variables remain positive and verify optimality, $h < h^{AA} = ((-1+\theta_m)^2(5-2(1+4\theta_r)\ \theta_m+\theta_r\ (2+3\theta_r)\theta_m^2)(c^2+4ab\gamma))/(4b^2(-2+\theta_m+\theta_r\theta_m)^2\ \ (5-5(1+\theta_r)\ \theta_m+(1+3\theta_r+\theta_r^2)\theta_m^2)\gamma)$ needs to be met if the retailer can hold strategic inventory. Besides, the complete expressions of profits for scenarios AAI and AAN are as shown in Table 3.

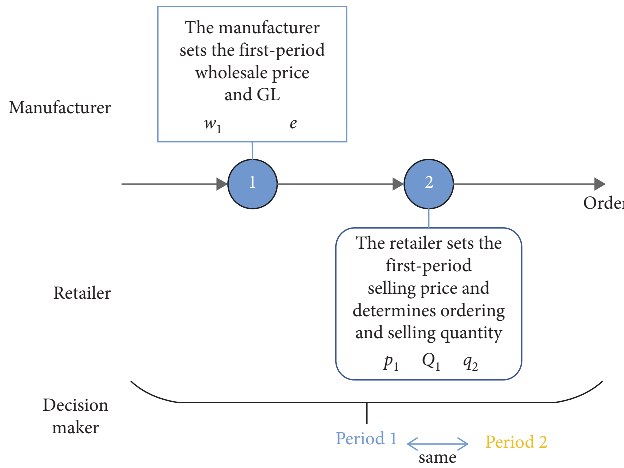


Figure 2: Decision process when the retailer does not hold strategic inventory.

$$
\begin{aligned}
A_1 =& \big(-310 + 460\theta_m - 257\theta_m^2 + 64\theta_m^3 - 6\theta_m^4 + 49\theta_r^7\theta_m^6 + 7\theta_r^6\theta_m^5(-72 + 23\theta_m) + \theta_r^5\theta_m^4\big(2110 - 1292\theta_m + 211\theta_m^2\big)\\
& + \theta_r^4\theta_m^3(-4620 + 4014\theta_m\\
& - 1248\theta_m^2 + 139\theta_m^3\big) + \theta_r\big(922 - 584\theta_m - 105\theta_m^2 + 132\theta_m^3 - 22\theta_m^4\big) + \theta_r^3\theta_m^2\big(5591 - 5940\theta_m + 2558\theta_m^2 - 540\theta_m^3 + 46\theta_m^4\big)\\
& + \theta_r^2\theta_m(-3548 + 3951\\
& * \theta_m - 1876\theta_m^2 + 526\theta_m^3 - 88\theta_m^4 + 6\theta_m^5)\big),\\
A_2 =& \big(-17 + 4(12 + 5\theta_r)\theta_m + \big(-35 - 74\theta_r + 7\theta_r^2\big)\theta_m^2 + \big(10 + 40\theta_r + 34\theta_r^2 - 16\theta_r^3\big)\theta_m^3 + \big(-1 - 6\theta_r - 11\theta_r^2 - 4\theta_r^3 + 5\theta_r^4\big)\theta_m^4\big),\\
A_3 =& \big(922 - 4(496 + 887\theta_r)\theta_m + \big(1681 + 6558\theta_r + 5591\theta_r^2\big)\theta_m^2 - 4\big(176 + 1153\theta_r + 2126\theta_r^2 + 1155\theta_r^3\big)\theta_m^3\\
& + 2\big(73 + 764\theta_r + 2313\theta_r^2\\
& + 2710\theta_r^3 + 1055\theta_r^4\big)\theta_m^4 - 4\big(3 + 58\theta_r + 266\theta_r^2 + 505\theta_r^3 + 425\theta_r^4 + 126\theta_r^5\big)\theta_m^5\\
& + \theta_r\big(12 + 86\theta_r + 240\theta_r^2 + 325\theta_r^3 + 210\theta_r^4 + 49\theta_r^5\big)\theta_m^6\big),\\
A_4 =& (-2 + \theta_m + \theta_r\theta_m),\\
A_5 =& \big(-34 + (41 + 61\theta_r)\theta_m - 2\big(8 + 25\theta_r + 18\theta_r^2\big)\theta_m^2 + \big(2 + 10\theta_r + 15\theta_r^2 + 7\theta_r^3\big)\theta_m^3\big)^2,\\
A_6 =& (-3 + \theta_m + 2\theta_r\theta_m)^2\big(17 - 2(7 + 10\theta_r)\theta_m + \big(3 + 8\theta_r + 6\theta_r^2\big)\theta_m^2\big),\\
A_7 =& \big(17 - 12\theta_m + 2\theta_m^2\big),\\
A_8 =& \big(-34 + 41\theta_m - 16\theta_m^2 + 2\theta_m^3\big).
\end{aligned}
\tag{A.1.}
$$

Table 2: Optimal decision expressions for scenarios AAI and AAN.

	AAI	AAN
e	$c/(2b\gamma)$	$c/(2b\gamma)$
w_1	$\left(\begin{array}{c} c^2(-1+\theta_m)\left(\begin{array}{c}-52+71\theta_m-30\theta_m^2+4\theta_r^3(9-2\theta_m)\theta_m^2+4\theta_m^3-7\theta_r^4\theta_m^3\\ +\theta_r^2\theta_m(-61+6\theta_m+13\theta_m^2)+2\theta_r(17+22\theta_m-33\theta_m^2+8\theta_m^3)\end{array}\right)+\\ 4b\left(\begin{array}{c}2a(-1+\theta_m)^2(-3+\theta_m+2\theta_r\theta_m)^2-bh(-2+\theta_m+\theta_r\theta_m)^2\\ *(1+2(-2+\theta_r)\theta_m+(1+2\theta_r-2\theta r)\theta_m^2)\end{array}\right)\gamma\end{array}\right)/$ $\left(4b^2(-1+\theta_r)(-1+\theta_m)*\left(\begin{array}{c}34-(41+61\theta_r)\theta_m+2(8+25\theta_r+18\theta_r^2)\theta_m^2\\ -(2+10\theta_r+15\theta_r^2+7\theta_r^3)\theta_m^3\end{array}\right)\gamma\right)$	$(c^2(3-2\theta_r-2\theta_m+\theta_r^2\theta_m)-4ab(-1+\theta_m)\gamma)/$ $(4b^2(-1+\theta_r)(-2+\theta_m+\theta_r\theta_m)\gamma)$
Q_1	$-\left((-1+\theta_r\theta_m)\left(\begin{array}{c}-c^2(-1+\theta_m)^2(13-2(5+8\theta_r)\theta_m+(2+6\theta_r+5\theta_r^2)\theta_m^2)\\ +2b\left(\begin{array}{c}bh(-2+\theta_m+\theta_r\theta_m)^2*(9-2(5+4\theta_r)\theta_m+(2+6\theta_r+\theta_r^2)\theta_m^2)\\ -2a(-1+\theta_m)^2(13-2(5+8\theta_r)\theta_m+(2+6\theta_r+5\theta_r^2)\theta_m^2)\end{array}\right)*\gamma\end{array}\right)\right)/$ $(4b(-1+\theta_m)^2(-34+(41+61\theta_r)\theta_m-2(8+25\theta_r+18\theta_r^2)\theta_m^2+(2+10\theta_r+15\theta_r^2+7\theta_r^3)\theta_m^3)\gamma)$	$((-1+\theta_r\theta_m)(c^2+4ab\gamma)/8b(-2+\theta_m+\theta_r\theta_m)\gamma)$
I	$(c^2(-1+\theta_m)^2(5-2(1+4\theta_r)\theta_m+\theta_r(2+3\theta_r)\theta_m^2)-4b(-a(-1+\theta_m)^2(5-2(1+4\theta_r)\theta_m+\theta_r(2+3\theta_r)*\theta_m^2)+$ $bh(-2+\theta_m+\theta_r\theta_m)^2(5-5(1+\theta_r)\theta_m+(1+3\theta_r+\theta_r^2)\theta_m^2))\gamma)/(8b(-1+\theta_m)^2(17-2(6+11\theta_r)*\theta_m+(2+8\theta_r+7\theta_r^2)\theta_m^2)\gamma)$	
p_1	$\left(\begin{array}{c}c^2(-1+\theta_m)(-120+9(17+23\theta_r)\theta_m-2(31+91\theta_r+58\theta_r^2)\theta_m^2+(8+38\theta_r+53\theta_r^2+21\theta_r^3)\theta_m^3)+4*\\ b\left(\begin{array}{c}bh(-2+\theta_m+\theta_r\theta_m)^2(-1-2(-2+\theta_r)\theta_m+(-1-2\theta_r+2\theta_r^2)\theta_m^2)\\ +a(-1+\theta_m)(-52+(71+85\theta_r)*\theta_m-2(15+41\theta_r+22\theta_r^2)\theta_m^2+(4+18\theta_r+23\theta_r^2+7\theta_r^3)\theta_m^3)\end{array}\right)\gamma\end{array}\right)/$ $(8b^2(-1+\theta_m)(-34+(41+61\theta_r)*\theta_m-2(8+25\theta_r+18\theta_r^2)\theta_m^2+(2+10\theta_r+15\theta_r^2+7\theta_r^3)\theta_m^3)\gamma)$	$(c^2(-7+(4+3\theta_r)\theta_m)+4ab(-3+(2+\theta_r)\theta_m)\gamma)/(8b^2(-2+\theta_m+\theta_r\theta_m)\gamma)$
w_2	$\left(\begin{array}{c}c^2(-1+\theta_m)\left(\begin{array}{c}-23+20\theta_m+\theta_r^2(-22+\theta_m)\theta_m-4\theta_m^2\\ +7\theta_r^3\theta_m^2+\theta_r(17+14\theta_m-10\theta_m^2)\end{array}\right)\\ -4b\left(\begin{array}{c}2a(-1+\theta_m)^2(-3+\theta_m+2\theta_r\theta_m)+bh\\ *(-10+15(1+\theta_r)\theta_m-(7+16\theta_r+7\theta_r^2)\theta_m^2+(1+4\theta_r+4\theta_r^2+\theta_r^3)\theta_m^3)\end{array}\right)\gamma\end{array}\right)/\left(\begin{array}{c}4b^2(-1+\theta_r)(-1+\theta_m)\\ *(17-2(6+11\theta_r)\theta_m+(2+8\theta_r+7\theta_r^2)\theta_m^2)\gamma\end{array}\right)$	$(c^2(3-2\theta_r-2\theta_m+\theta_r^2\theta_m)-4ab(-1+\theta_m)\gamma)/(4b^2(-1+\theta_r)(-2+\theta_m+\theta_r\theta_m)\gamma)$
Q_2	$\left((-1+\theta_r\theta_m)\left(c^2(-1+\theta_m)^2(-3+\theta_m+2\theta_r\theta_m)+2b\left(\begin{array}{c}2a(-1+\theta_m)^2(-3+\theta_m+2\theta_r\theta_m)\\ +bh(-10+15(1+\theta_r)\theta_m-(7+16\theta_r+7\theta_r^2)\theta_m^2+(1+4\theta_r+4\theta_r^2+\theta_r^3)\theta_m^3)\end{array}\right)\gamma\right)\right)/$ $(4b(-1+\theta_m)^2(17-2(6+11\theta_r)\theta_m+(2+8\theta_r+7\theta_r^2)\theta_m^2)\gamma)$	$((-1+\theta_r\theta_m)(c^2+4ab\gamma))/(8b(-2+\theta_m+\theta_r\theta_m)\gamma)$
p_2	$\left(\begin{array}{c}c^2(-1+\theta_m)(57-2(22+35\theta_r)\theta_m+(8+28\theta_r+21\theta_r^2)\theta_m^2)\\ +4b\left(\begin{array}{c}a(-1+\theta_m)(23-2(10+13\theta_r)\theta_m+(4+12\theta_r+7\theta_r^2)\theta_m^2)\\ +bh(-10+15(1+\theta_r)\theta_m-(7+16\theta_r+7\theta_r^2)\theta_m^2+(1+4\theta_r+4\theta_r^2+\theta_r^3)\theta_m^3)\end{array}\right)*\gamma\end{array}\right)/$ $(8b^2(-1+\theta_m)(17-2(6+11\theta_r)\theta_m+(2+8\theta_r+7\theta_r^2)\theta_m^2)\gamma)$	$(c^2(-7+(4+3\theta_r)\theta_m)+4ab(-3+(2+\theta_r)\theta_m)\gamma)/(8b^2(-2+\theta_m+\theta_r\theta_m)\gamma)$

4.2. Strategic Inventory Models with Only One Decision-Maker's Altruistic Preference. In scenario ARI, only the manufacturer is altruistic, while the retailer chooses to hold strategic inventory and focuses on her profit maximization. The utility functions are as follows:

$$\begin{aligned}
\max U_{r2}^{ARI} &= p_2^{ARI}\left(a - bp_2^{ARI} + ce^{ARI}\right) - w_2^{ARI}\left(a - bp_2^{ARI} + ce^{ARI} - I^{ARI}\right)\\
\max U_{m2}^{ARI} &= \left(w_2^{ARI} - \gamma e^{ARI^2}\right)\left(a - bp_2^{ARI} + ce^{ARI} - I^{ARI}\right) + \theta_m\left(\left(p_2^{ARI} - w_2^{ARI}\right)\left(a - bp_2^{ARI} + ce^{ARI}\right) + w_2^{ARI} I^{ARI}\right)\\
\max U_{r}^{ARI} &= \left(p_1^{ARI} - w_1^{ARI}\right)\left(a - bp_1^{ARI} + ce^{ARI}\right) + \left(w_2^{ARI} - h - w_1^{ARI}\right)I^{ARI} + \left(p_2^{ARI} - w_2^{ARI}\right)\left(a - bp_2^{ARI} + ce^{ARI}\right)\\
\max U_{m}^{ARI} &= \left(w_1^{ARI} - \gamma e^{ARI^2}\right)\left(a - bp_1^{ARI} + ce^{ARI} + I^{ARI}\right) + \left(w_2^{ARI} - \gamma e^{ARI^2}\right)\left(a - bp_2^{ARI} + ce^{ARI} - I^{ARI}\right)\\
&\quad + \theta_m\left(\left(p_1^{ARI} - w_1^{ARI}\right)\left(a - bp_1^{ARI} + ce^{ARI}\right) + \left(p_2^{ARI} - w_2^{ARI}\right)\left(a - bp_2^{ARI} + ce^{ARI}\right) - \left(w_1^{ARI} + h - w_2^{ARI}\right)I^{ARI}\right).
\end{aligned} \tag{7}$$

In scenario ARN, the utility functions are as follows:

$$\begin{aligned}
\max U_{r1}^{ARN} &= \left(p_1^{ARN} - w_1^{ARN}\right)\left(a - bp_1^{ARN} + ce^{ARN}\right),\\
\max U_{m1}^{ARN} &= \left(w_1^{ARN} - \gamma e^{ARN^2}\right)\left(a - bp_1^{ARN} + ce^{ARN}\right) + \theta_m\left(p_1^{ARN} - w_1^{ARN}\right)\left(a - bp_1^{ARN} + ce^{ARN}\right).
\end{aligned} \tag{8}$$

Both of them are similar to those of AAI and AAN. From the calculation, the retailer can choose to hold strategic inventory when $h < h^{AR} = -((-1+\theta_m)^2 \, (-5+2\theta_m)(c^2+4ab\gamma))/(4b^2(-2+\theta_m)^2(5-5\theta_m+\theta_m^2)\gamma)$.

In scenario RAI, the altruistic retailer holds strategic inventory, while the manufacturer considers his profit maximization. The utility functions are as follows:

$$\begin{aligned}
\max U_{r2}^{RAI} &= p_2^{RAI}\left(a - bp_2^{RAI} + ce^{RAI}\right) - w_2^{RAI}\left(a - bp_2^{RAI} + ce^{RAI} - I^{RAI}\right) + \theta_r\left(\left(w_2^{RAI} - \gamma e^{RAI^2}\right)\left(a - bp_2^{RAI} + ce^{RAI} - I^{RAI}\right)\right),\\
\max U_{m2}^{RAI} &= \left(w_2^{RAI} - \gamma e^{RAI^2}\right)\left(a - bp_2^{RAI} + ce^{RAI} - I^{RAI}\right),\\
\max U_{r}^{RAI} &= p_1^{RAI}\left(a - bp_1^{RAI} + ce^{RAI}\right) - w_1^{RAI}\left(a - bp_1^{RAI} + ce^{RAI} + I^{RAI}\right) + p_2^{RAI}\left(a - bp_2^{RAI} + ce^{RAI}\right) - w_2^{RAI}\left(a - bp_2^{RAI}\right.\\
&\quad \left. + ce^{RAI} - I^{RAI}\right) - hI^{RAI} + \theta_r\left(\left(w_1^{RAI} - \gamma e^{RAI^2}\right)\left(a - bp_1^{RAI} + ce^{RAI} + I^{RAI}\right)\right.\\
&\quad \left. + \left(w_2^{RAI} - \gamma e^{RAI^2}\right)\left(a - bp_2^{RAI} + ce^{RAI} - I^{RAI}\right)\right),\\
\max U_{m}^{RAI} &= \left(w_1^{RAI} - \gamma e^{RAI^2}\right)\left(a - bp_1^{RAI} + ce^{RAI} + I^{RAI}\right) + \left(w_2^{RAI} - \gamma e^{RAI^2}\right)\left(a - bp_2^{RAI} + ce^{RAI} - I^{RAI}\right).
\end{aligned} \tag{9}$$

In scenario RAN, the utility functions are as follows:

$$\begin{aligned}
\max U_{r1}^{RAN} &= \left(p_1^{RAN} - w_1^{RAN}\right)\left(a - bp_1^{RAN} + ce^{RAN}\right) + \theta_r\left(w_1^{RAN} - \gamma e^{RAN^2}\right)\left(a - bp_1^{RAN} + ce^{RAN}\right),\\
\max U_{m1}^{RAN} &= \left(w_1^{RAN} - \gamma e^{RAN^2}\right)\left(a - bp_1^{RAN} + ce^{RAN}\right).
\end{aligned} \tag{10}$$

Table 3: The complete expressions of profits in scenarios AAI and AAN.

	AAI	AAN
Π_r	$(c^4(-1+\theta_m)^3A_1+4bc^2(-1+\theta_m)^2(-1+\theta_r\theta_m)(-bhA_4^2(-59+55\theta_m-18\theta_m^2+2\theta_m^3+\theta_r^4\theta_m^3(-41+21\theta_m)+\theta_r^3*$ $\theta_m^2(179-130\theta_m+31\theta_m^2)+\theta_r^2\theta_m(-261+218\theta_m-91\theta_m^2+14\theta_m^3)+\theta_r(127-66\theta_m+29\theta_m^2-12\theta_m^3+2\theta_m^4))+$ $2a(-1+\theta_m)(310-460\theta_m+257\theta_m^2-64\theta_m^3+6\theta_m^4+49\theta_r^6\theta_m^5+7\theta_r^5\theta_m^4(-65+23\theta_m)+\theta_r^4\theta_m^3(1655-1131*$ $\theta_m+211\theta_m^2)+\theta_r^3\theta_m^2(-2965+2883\theta_m-1037\theta_m^2+139\theta_m^3)+\theta_r^2\theta_m(2626-3057\theta_m+1521\theta_m^2-401\theta_m^3+46*$ $\theta_m^4)+\theta_r(-922+894\theta_m-355\theta_m^2+125\theta_m^3-42\theta_m^4+6\theta_m^5)))\gamma+8b^2(-2abh(-1+\theta_m)^2A_4^2(59-55\theta_m+18\theta_m^2-$ $2\theta_m^3+\theta_r^5\theta_m^4(-41+21\theta_m)+\theta_r^4\theta_m^3(220-151\theta_m+31\theta_m^2)+\theta_r(-127+7\theta_m+26\theta_m^2-6\theta_m^3)+2\theta_r^3\theta_m^2(-220+$ $174\theta_m-61\theta_m^2+7\theta_m^3)+2\theta_r^2\theta_m(194-142\theta_m+60\theta_m^2-13\theta_m^3+\theta_m^4))+b^2h^2A_4^4(76-184\theta_m+181\theta_m^2-91\theta_m^3+$ $22\theta_m^4-2\theta_m^5+\theta_r^5\theta_m^4(-9+7\theta_m)+\theta_r^4\theta_m^3(96-129\theta_m+43\theta_m^2)+\theta_r^3\theta_m^2(-289+471\theta_m-237\theta_m^2+35\theta_m^3)+\theta_r^2*$ $\theta_m(344-593\theta_m+327\theta_m^2-53\theta_m^3-5\theta_m^4)+\theta_r(-144+180\theta_m+21\theta_m^2-123\theta_m^3+66\theta_m^4-10\theta_m^5))+2a^2*$ $(-1+\theta_m)^3A_1)\gamma^2)/(32b^3(-1+\theta_r)(-1+\theta_m)^3A_5\gamma^2)$	$((-1+3\theta_r+\theta_r^2(-4+\theta_m)\theta_m+\theta_r^3\theta_m^2)*$ $(c^2+4ab\gamma)^2)/(32b^3(-1+\theta_r)A_4^2\gamma^2)$
Π_m	$((-1+\theta_r\theta_m)(-c^4(-1+\theta_m)^4A_6-4bc^2(-1+\theta_m)^2(2a(-1+\theta_m)^2A_6+bhA_4^2A_2)\gamma-4b^2(4a^2(-1+\theta_m)^4A_6-b^2h^2A_4^4*$ $(-34+8(12+5\theta_r)\theta_m-2(43+58\theta_r+\theta_r^2)\theta_m^2+(28+88\theta_r+28\theta_r^2-8\theta_r^3)\theta_m^3+(-3-16\theta_r-20\theta_r^2+4\theta_r^3+\theta_r^4)\theta_m^4)+$ $4abh(-1+\theta_m)^2A_4^2A_2)\gamma^2))/(8b^3(-1+\theta_r)(-1+\theta_m)^3A_5\gamma^2)$	$-(-1+\theta_m)(-1+\theta_r\theta_m)(c^2+4ab\gamma)^2/16b^3(-1+\theta_r)A_4^2\gamma^2$
Π	$(c^4(-1+\theta_m)^2A_3+4bc^2(-1+\theta_m)^2(-1+\theta_r\theta_m)(-bhA_4^2(-127+3(40+87\theta_r)\theta_m-(38+164\theta_r+179\theta_r^2)\theta_m^2+$ $(4+26\theta_r+56\theta_r^2+41\theta_r^3)\theta_m^3)+2a(-922+2(992+1313\theta_r)\theta_m-(1681+4574\theta_r+2965\theta_r^2)\theta_m^2+(704+$ $2931\theta_r+3930\theta_r^2+1655\theta_r^3)\theta_m^3-(146+824\theta_r+1695\theta_r^2+1490\theta_r^3+455\theta_r^4)\theta_m^4+(12+86\theta_r+240\theta_r^2+$ $325\theta_r^3+210\theta_r^4+49\theta_r^5)\theta_m^5))\gamma+8b^2(b^2h^2A_4^4(-4+\theta_m+3\theta_r\theta_m)^2(9-2(5+4\theta_r)\theta_m+(2+6\theta_r+\theta_r^2)\theta_m^2)-$ $2abh(-1+\theta_m)^2A_4^2(127-4(30+97\theta_r)\theta_m+(38+284\theta_r+440\theta_r^2)\theta_m^2-4(1+16\theta_r+55\theta_r^2+55\theta_r^3)\theta_m^3+$ $\theta_r(4+26\theta_r+56\theta_r^2+41\theta_r^3)\theta_m^4)+2a^2(-1+\theta_m)^2A_3)\gamma^2)/(32b^3(-1+\theta_m)^2A_5\gamma^2)$	$((3-2(1+2\theta_r)\theta_m+\theta_r(2+\theta_r)\theta_m^2)*$ $(c^2+4ab\gamma)^2)/(32b^3A_4^2\gamma^2)$

Both of them are similar to those involved in scenarios AAI and AAN. Through the calculation, the retailer can choose to hold strategic inventory when $h < h^{RA} = (c^2 + 4ab\gamma)/(16b^2\gamma)$.

Proposition 2. *For MIGPs, when only one supply chain member exhibits altruism, the optimal decisions are shown in Table 4. In addition, the complete expressions of profits for situations ARI, ARN, RAI, and RAN are shown in Table 5.*

$$A_7 = \left(17 - 12\theta_m + 2\theta_m^2\right);\ A_8 = \left(-34 + 41\theta_m - 16\theta_m^2 + 2\theta_m^3\right). \tag{11}$$

5. Comparison and Analysis of Equilibrium Results

This paper compares and investigates the equilibrium results of six scenarios (AAI, AAN, ARI, ARN, RAI, and RAN). The work further analyzes the role of strategic inventory in the context of altruism. In addition, the influence of altruism on the GL, pricing, and profits of green products is also explored.

5.1. The Influence of Strategic Inventory. In considering three types of differentiation scenarios (AA, AR, and RA), this paper uses superscript "I" to represent holding strategic inventory and superscript "N" to represent an absence of strategic inventory. This section compares and analyzes the impacts of strategic inventory on decision-making and profits separately.

Proposition 3. *For MIGPs, when the decision-makers exhibit altruism simultaneously or alone, the influence of holding strategic inventory on decisions is as follows:*

(1) For the manufacturer, strategic inventory does not affect GL $e^I = e^N$ but promotes first-period wholesale prices $w_1^I > w_1^N$ and reduces second-period wholesale prices $w_2^I < w_2^N$

(2) For the retailer, strategic inventory has the following impact on her decisions:

(a) Second-period order quantities of the retailer satisfy $Q_2^I < Q_2^N$

(b) Selling prices of the retailer satisfy $p_1^I > p_1^N$ and $p_2^I < p_2^N$

(c) Selling quantities of the retailer satisfy $q_1^I < q_1^N$, and $q_2^I > q_2^N$

(3) When supply chain members have altruistic preferences simultaneously or alone, the effect of strategic inventory on the first-period order quantities is different

The GL of MIGPs is not affected by the retailer's purchasing strategies. This result verifies the proposition of Dey et al. [9]. At the same time, to control the quantity of inventory and reduce the retailer's bargaining power, the manufacturer increases first-period wholesale prices $w_1^I > w_1^N$. Besides, to encourage the retailer with strategic inventory to continue to buy goods in period 2, the manufacturer further reduces second-period wholesale prices $w_2^I < w_2^N$, showing that strategic inventory can still have a bargaining effect even if there is an altruistic preference.

Due to change in wholesale prices, the retailer correspondingly increases first-period selling prices $p_1^I > p_1^N$ and reduces second-period selling prices $p_2^I < p_2^N$. Moreover, due to the presence of strategic inventory, even if the manufacturer reduces second-period wholesale prices, the retailer still does not order more goods $Q_2^I < Q_2^N$. As shown in Figures 3(c), the altruistic retailer may order more goods in period 1 when she holds strategic inventory $Q_1^{RAI} > Q_1^{RAN}$. Interesting, as shown in Figures 3(a) and 3(b), when only the manufacturer exhibits altruism or both members are altruistic, there are differentiation thresholds $h_{Q_1}^{AR}$ and $h_{Q_1}^{AA}$. When $0 < h < h_{Q_1}^{AR}$ or $0 < h < h_{Q_1}^{AA}$, the first-period ordering quantity satisfies $Q_1^I > Q_1^N$. Otherwise, affected by holding costs, wholesale prices, and altruistic preferences, the retailer may order few products when she holds inventory in period 1.

$$\begin{aligned} h_{Q_1}^{AA} &= \frac{(-1+\theta_m)^2\left(9 - 2(4+5\theta_r)\theta_m + \left(2 + 4\theta_r + 3\theta_r^2\right)\theta_m^2\right)\left(c^2 + 4ab\gamma\right)}{4b^2(-2+\theta_m+\theta_r\theta_m)^2\left(9 - 2(5+4\theta_r)\theta_m + \left(2 + 6\theta_r + \theta_r^2\right)\theta_m^2\right)\gamma}, \\ h_{Q_1}^{AR} &= \frac{(-1+\theta_m)^2\left(9 - 8\theta_m + 2\theta_m^2\right)\left(c^2 + 4ab\gamma\right)}{4b^2(-2+\theta_m)^2\left(9 - 10\theta_m + 2\theta_m^2\right)\gamma}. \end{aligned} \tag{12}$$

Proposition 4. *For MIGPs, when supply chain members have altruistic preferences, the influence of strategic inventory on supply chain members' profits is as follows:*

(1) The retailer holding strategic inventory may not necessarily improve her profits.

(2) When both decision-makers are altruistic, or only the manufacturer is altruistic, the manufacturer may not benefit from strategic inventory. However, the manufacturer can benefit from strategic inventory when only the retailer is altruistic.

(3) Strategic inventory does not necessarily lead to increased profits for the green supply chain.

The retailer's strategic inventory does not necessarily improve her profits. It is worth noting that, in different altruistic scenarios, $\Pi_r^I - \Pi_r^N$ has differentiated thresholds. As shown in Figures 4(a) and 4(b), when $0 < h < h_{\Pi_r}^{AA}$, $0 < h < h_{\Pi_r}^{AR}$, or $0 < h < h_{\Pi_r}^{RA}$, the retailer's profits satisfy $\Pi_r^I > \Pi_r^N$. This shows that when there are altruistic decision-makers in the green supply chain, the retailer can obtain more profits by holding strategic inventory while facing lower holding costs. Moreover, it is evident from Figure 4(c) that when the retailer exhibits a strong altruistic preference, she does not choose strategic inventory regardless of how low the holding cost is.

In some previous studies, it is generally argued that manufacturers can benefit from strategic inventory [9, 27]. This conclusion is still true when only the retailer is altruistic, as shown in Figure 5(c). Notably, the differentiation altruistic scenarios also affect thresholds of the manufacturer's profits. When $0 < h < h_{\Pi_m}^{AA}$ or $0 < h < h_{\Pi_m}^{AR}$, the manufacturer's profits satisfy $\Pi_m^I < \Pi_m^N$ in Figures 5(a) and 5(b). Only when the manufacturer's altruistic preference is significant does the wholesale prices drop greatly, which may lead to the manufacturer's profit being lower when the retailer holds inventory.

Under the combined effects of their profit changes, the difference in supply chain profits is shown in Figure 6. When $0 < h < h_{\Pi}^{AA}$, $0 < h < h_{\Pi}^{AR}$, or $0 < h < h_{\Pi}^{RA}$, the supply chain's profits satisfy $\Pi^I > \Pi^N$. Due to the complexity of the function expressions of holding costs, the specific expressions are shown in Appendix B.

In general, when considering decision-makers' behavioral preferences, the role of strategic inventory changes. It is noteworthy that whether the retailer holds strategic inventory does not affect the GL of MIGPs set by the manufacturer. Second, strategic inventory is still an effective bargaining tool and involves non-single-period cooperation, but it may not necessarily bring greater benefits to members. Finally, members' simultaneous or individual preferences have a great impact on the role of strategic inventory, as shown in Figures 3–6. Therefore, different scenarios of altruistic preferences need to be further analyzed.

5.2. The Influence of Altruistic Preference. This section first discusses the impact of decision-makers having altruistic preferences simultaneously or alone on alternative procurement strategies and analyses the influence of retailer altruism on decision-making and profits. Finally, the impact of the manufacturer's altruism is studied.

Corollary 1. *In three different scenarios (AAI, ARI, and RAI), the influence of altruistic preference on the range of strategic inventory that the retailer can hold is as follows:*

(1) When only the manufacturer is altruistic, the scope of the strategic inventory that the retailer can hold decreases with the manufacturer's altruism

(2) When only the retailer has an altruistic preference, it does not affect the scope of strategic inventory

(3) When both decision-makers exhibit altruism, the retailer's altruistic preference expands the range of strategic inventory, while the manufacturer's altruism reduces the field of strategic inventory

As shown in Figures 7(a) and 7(c), the manufacturer's altruistic preference reduces the range of strategic inventory that the retailer can hold. This is mainly the case because the manufacturer's altruistic preference further reduces wholesale prices, which provides a better profit guarantee for the retailer such that she gives up strategic inventory under higher holding costs. As shown in Figure 7(b), when only the retailer is altruistic, the field of strategic inventory that the retailer can hold is not affected by her altruism. This is mainly the case because in scenario RAI, the retailer's altruism only affects the manufacturer's wholesale prices. However, when both decision-makers have altruistic preferences, the impact of the retailer's altruism on the range of strategic inventory is significantly different as shown in Figure 7(c). This is important because when both decision-makers are altruistic, the variables affected are not limited to wholesale prices, as shown in Proposition 5.

5.2.1. The Influence of Retailer's Altruistic Preference

Proposition 5. *In four scenarios (RAI, RAN, AAI, and AAN), the influence of the retailer's altruistic preference on decisions is as follows:*

(1) The GL satisfies $\partial e^{RAI}/\partial\theta_r = \partial e^{RAN}/\partial\theta_r = \partial e^{AAI}/\partial\theta_r = \partial e^{AAN}/\partial\theta_r$

(2) The wholesale prices in the first and second periods satisfy $(\partial w_1^{RAI}/\partial\theta_r) > (\partial w_2^{RAI}/\partial\theta_r) > 0$, $(\partial w_1^{AAI}/\partial\theta_r) > (\partial w_2^{AAI}/\partial\theta_r) > 0$, $(\partial w_1^{AAN}/\partial\theta_r) = (\partial w_2^{AAN}/\partial\theta_r) > 0$, $(\partial w_1^{RAN}/\partial\theta_r) = (\partial w_2^{RAN}/\partial\theta_r) > 0$

(3) The influence of the retailer's altruistic preference on her own decisions is complex, which is affected by the comprehensive scenario of the manufacturer's altruism and retailer's purchasing strategies, as shown in Table 6

Through calculation, the retailer's altruism only increases wholesale prices but does not affect the GL for MIGPs. Simultaneously, in different scenarios, the influence of the retailer's altruism on other decisions is different. When only the retailer is altruistic (RAI and RAN), the order quantities, selling prices, and sales quantities are not affected by her altruistic preference. When both members are altruistic (AAI and AAN), the retailer's altruistic preference promotes increased sales prices and decreased selling quantities. Interestingly, the effect of the retailer's altruism on the first-period purchase quantities is not only affected by different altruistic scenarios but also influenced by purchase strategies. If the retailer chooses not to hold strategic inventory, the first-period ordering quantities decrease with altruistic preference. However, if the retailer chooses to hold strategic inventory, the change in first-period ordering quantities and inventories is not monotonous, when $0 < h < h_{rQ_1}^{AA}$, $\partial Q_1^{AAI}/\partial\theta_r < 0$; when $h_{rQ_1}^{AA} < h < h^{AA}$, $\partial Q_1^{AAI}/\partial\theta_r > 0$; when $0 < h < h_{rI}^{AA}$, $\partial_I^{AAI}/\partial\theta_r < 0$; and when $h_{rI}^{AA} < h < h^{AA}$, $\partial I^{AAI}/\partial\theta_r > 0$, as shown in Figure 8. The difference in the thresholds needs to consider the impact of the first-period selling price affected by the retailer's altruism.

Table 4: Optimal decision expressions for scenarios ARI, ARN, RAI, and RAN.

	ARI	ARN	RAI	RAN
e	$(c/(2b\gamma))$	$(c/(2b\gamma))$	$(c/(2b\gamma))$	$(c/(2b\gamma))$
w_1	$(c^2(-1+\theta_m)(-52+71\theta_m-30\theta_m^2+4\theta_m^3)+4b\ (-bh(-2+\theta_m)^2 * (1-4\theta_m+\theta_m^2)+2a(3-4\theta_m+\theta_m^2)^2)\gamma)/(4b^2(-1+\theta_m)A_8\gamma)$	$(c^2(-3+2\theta_m)+4ab(-1+\theta_m)\gamma)/(4b^2(-2+\theta_m)\gamma)$	$(c^2(-26+17\theta_r)+4b(-9a+2bh)\gamma)/\ (68b^2(-1+\theta_r)\gamma)$	$(c^2(-3+2\theta_r)-4ab\gamma)/(8b^2(-1+\theta_r)\gamma)$
Q_1	$-((c^2(-1+\theta_m)^2(13-10\theta_m+2\theta_m^2)+2b(-bh(-2+\theta_m)^2(9-10\theta_m+2\theta_m^2)+2a(-1+\theta_m)^2(13-10\theta_m+2\theta_m^2))\gamma)/(4b(-1+\theta_m)^2A_8\gamma))$	$(c^2+4ab\gamma)/(16b\gamma-8b\theta_m\gamma)$	$(52a-72bh+(13c^2/b\gamma))/136$	$(c^2+4ab\gamma)/(16b\gamma)$
I	$-((c^2(-1+\theta_m)^2(-5+2\theta_m)+4b(a(-1+\theta_m)^2(-5+2\theta_m)+bh*(-2+\theta_m)^2\ (5-5\theta_m+\theta_m^2))\gamma)/(8b(-1+\theta_m)^2A_7\gamma))$		$5(c^2+4b(a-4bh)\gamma)/(136b\gamma)$	-
p_1	$(c^2(120-273\theta_m+215\theta_m^2-70\theta_m^3+8\theta_m^4)+4b(-bh(-2+\theta_m)^2 * (1-4\theta_m+\theta_m^2)+a(52-123\theta_m+101\theta_m^2-34\theta_m^3+4\theta_m^4))\gamma)/(8b^2 * (-1+\theta_m)A_8\gamma)$	$(c^2(-7+4\theta_m)+4ab(-3+2\theta_m)\gamma)/(8b^2(-2+\theta_m)\gamma)$	$(15c^2+26ab\gamma-2b^2h\gamma)/(34b^2\gamma)$	$(7c^2+12ab\gamma)/(16b^2\gamma)$
w_2	$(c^2(-23+43\theta_m-24\theta_m^2+4\theta_m^3)+4b(2a(-3+\theta_m)\ (-1+\theta_m)^2+bh(-10+15\theta_m-7\theta_m^2+\theta_m^3))\gamma)/\ (4b^2(-1+\theta_m)A_7\gamma)$	$(c^2(-3+2\theta_m)+4ab(-1+\theta_m)\gamma)/(4b^2(-2+\theta_m)\gamma)$	$(c^2(-23+17\theta_r)-8b(3a+5bh)\gamma)/(68b^2(-1+\theta_r)\gamma)$	$(c^2(-3+2\theta_r)-4ab\gamma)/(8b^2(-1+\theta_r)\gamma)$
Q_2	$-((c^2(-3+\theta_m)(-1+\theta_m)^2+2b(2a(-3+\theta_m)(-1+\theta_m)^2+bh(-10+15\theta_m-7\theta_m^2+\theta_m^3))\gamma)/(4b(-1+\theta_m)^2A_7\gamma))$	$(c^2+4ab\gamma)/(16b\gamma-8b\theta_m\gamma)$	$(12a+20bh+(3c^2)/(b\gamma))/68$	$(c^2+4ab\gamma)/(16b\gamma)$
p_2	$(c^2(-57+101\theta_m-52\theta_m^2+8\theta_m^3)+4b(bh(-10+15\theta_m-7\theta_m^2+\theta_m^3)+a(-23+43\theta_m-24\theta_m^2+4\theta_m^3))\gamma)/(8b^2(-1+\theta_m)A_7\gamma)$	$(c^2(-7+4\theta_m)+4ab(-3+2\theta_m)\gamma)/(8b^2(-2+\theta_m)\gamma)$	$(57c^2+92ab\gamma+40b^2h\gamma)/(136b^2\gamma)$	$(7c^2+12ab\gamma)/(16b^2\gamma)$

Table 5: The complete expressions of profits in scenarios ARI, ARN, RAI, and RAN.

	ARI	ARN	RAI	RAN
Π_r	$\begin{pmatrix} c^4(-1+\theta_m)^3(310-460\theta_m+257\theta_m^2-64\theta_m^3+6\theta_m^4)+ \\ 4bc^2*(-1+\theta_m)^2(-bh(-2+\theta_m)^2(-59+55\theta_m-18\theta_m^2+2\theta_m^3)+ \\ 2a*(-310+770\theta_m-717\theta_m^2+321\theta_m^3-70\theta_m^4+6\theta_m^5)) \\ \gamma+8b^2*(-2abh(2-3\theta_m+\theta_m^2)^2(-59+55\theta_m-18\theta_m^2+2\theta_m^3)+2a^2* \\ (-1+\theta_m)^3(310-460\theta_m+257\theta_m^2-64\theta_m^3+6\theta_m^4)+b^2h^2* \\ (-2+\theta_m)^4(-76+184\theta_m-181\theta_m^2+91\theta_m^3-22\theta_m^4+2\theta_m^5))*\gamma^2 \end{pmatrix}/(32b^3(-1+\theta_m)^3A_8^2\gamma^2)$	$(c^2+4ab\gamma)^2/$ $(32b^3(-2+\theta_m)^2\gamma^2)$	$\begin{pmatrix} c^4(-155+461\theta_r)+8bc^2(bh*(59-127\theta_r)+ \\ a(-155+461*\theta_r)) \\ \gamma+16b^2(2abh(59-127*\theta_r)+16b^2h^2(-19+36\theta_r)+ \\ a^2*(-155+461\theta_r))\gamma^2 \end{pmatrix}/$ $(18496b^3*(-1+\theta_r)\gamma^2)$	$((-1+3\theta_r)(c^2+4ab\gamma)^2)/$ $(128b^3(-1+\theta_r)\gamma^2)$
Π_m	$-\begin{pmatrix} c^4(-3+\theta_m)^2(-1+\theta_m)^4(17-14\theta_m+3\theta_m^2)+ \\ 4bc^2(-1+\theta_m)^2*(2a(3-4\theta_m+\theta_m^2)^2(17-14\theta_m+3\theta_m^2)- \\ bh(-2+\theta_m)^2(17-48*\theta_m+35\theta_m^2-10\theta_m^3+\theta_m^4)) \\ \gamma+4b^2(4a^2(-3+\theta_m)^2(-1+\theta_m)^4*(17-14\theta_m+3\theta_m^2)- \\ 4abh(2-3\theta_m+\theta_m^2)^2(17-48\theta_m+35\theta_m^2-10\theta_m^3+\theta_m^4))+ \\ b^2h^2(-2+\theta_m)^4(34-96\theta_m+86\theta_m^2-28\theta_m^3+3\theta_m^4)\gamma^2 \end{pmatrix}/(8b^3(-1+\theta_m)^3A_8^2\gamma^2)$	$-((-1+\theta_m)(c^2+4ab\gamma)^2/$ $(16b^3(-2+\theta_m)^2\gamma^2))$	$(-9c^4+8bc^2(-9a+2bh)\gamma-16b^2*(9a^2-4abh+8b^2h^2)\gamma^2)/$ $(544b^3*(-1+\theta_r)\gamma^2)$	$-((c^2+4ab\gamma)^2/$ $64b^3(-1+\theta_r)\gamma^2)$
Π	$-\left(\left(\begin{matrix} c^4(-1+\theta_m)^2(-922+1984\theta_m-1681\theta_m^2+704\theta_m^3-146\theta_m^4+12\theta_m^5) \\ +4bc^2(-1+\theta_m)^2\begin{pmatrix} -bh(-2+\theta_m)^2(-127+120\theta_m-38*\theta_m^2+4\theta_m^3) \\ +2a(-922+1984\theta_m-1681\theta_m^2+704\theta_m^3-146\theta_m^4+12\theta_m^5) \end{pmatrix} \\ \gamma+8b^2\begin{pmatrix} -b^2h^2(-4+\theta_m)^2(-2+\theta_m)^4(9-10\theta_m+2\theta_m^2)-2abh(2-3\theta_m+\theta_m^2)^2(-127+120\theta_m-38\theta_m^2+4\theta_m^3) \\ +2a^2(-1+\theta_m)^2(-922+1984\theta_m-1681\theta_m^2+704\theta_m^3-146\theta_m^4+12\theta_m^5) \end{pmatrix}*\gamma^2 \end{matrix}\right)\right)/$ $(32b^3(34-75\theta_m+57\theta_m^2-18\theta_m^3+2\theta_m^4)^2\gamma^2)$	$-((-3+2\theta_m)(c^2+4ab\gamma)^2/$ $(32b^3(-2+\theta_m)^2\gamma^2))$	$(461c^4+8bc^2(461a-127bh)*\gamma$ $+16b^2(461a^2-254abh+576b^2h^2)\gamma^2)/(18496b^3\gamma^2)$	$(3(c^2+4ab\gamma)^2/128b^3\gamma^2)$

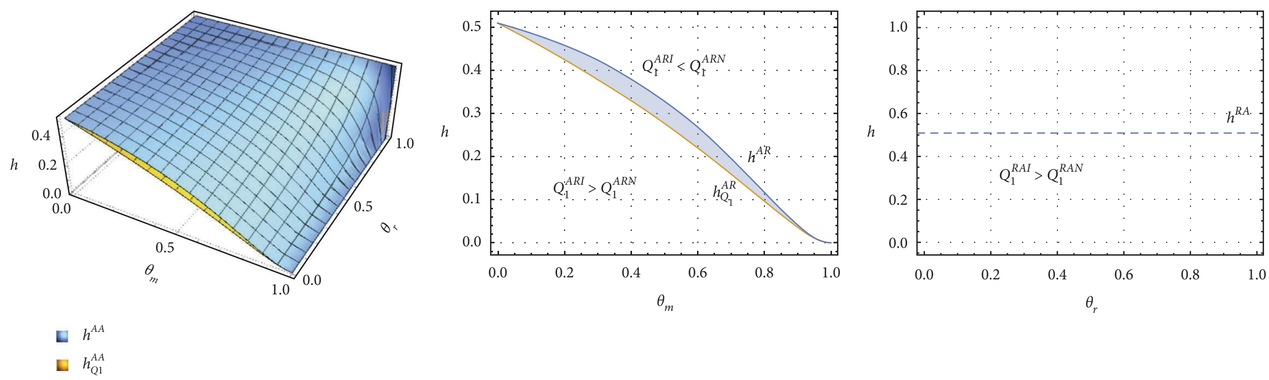


Figure 3: Thresholds of the first-period order quantities for different altruistic scenarios ($a = 1, b = 0.5, c = 0.2, \gamma = 1$). (a) Both members are altruistic. (b) Only the manufacturer is altruistic. (c) Only the retailer is altruistic.

Proposition 6. *In four scenarios (RAI, RAN, AAI, and AAN), the impacts of the retailer's altruistic preference on profits are as follows:*

(1) *The retailer's altruism reduces her profits and increases the manufacturer's profits.*

(2) *However, only in scenarios AAI and AAN do the supply chain's profits decrease with the retailer's altruistic preference. Otherwise, the supply chain's profits are not affected by the retailer's altruism.*

When only the retailer is altruistic, the manufacturer's wholesale prices increase as the retailer's level of altruism increases. However, the retailer's decisions are not impacted by her altruistic preference. Therefore, the manufacturer's profits increase as the retailer's level of altruism increases, while the retailer's profits decline. Since the increase in the manufacturer's profits is equal to the decrease in the retailer's profits, the supply chain's profits satisfy $\partial_{\Pi}^{RAI}/\partial\theta_r = 0$ and $\partial_{\Pi}^{RAN}/\partial\theta_r = 0$, as shown in Figures 9(a) and 9(c).

When both the retailer and manufacturer are altruistic, the manufacturer's profits still increase as the retailer's level of altruism increases, while the retailer's profits decrease. However, the rate at which the manufacturer's profits increases is lower than the rate at which the retailer's profits decline, which leads to $\partial_{\Pi}^{AAI}/\partial\theta_r < 0$ and $\partial_{\Pi}^{AAN}/\partial\theta_r < 0$, as shown in Figures 9(b) and 9(d). Therefore, the retailer's altruism is not necessarily beneficial to green supply chains.

5.2.2. The Influence of Manufacturer's Altruistic Preference

Proposition 7. *In four scenarios (ARI, ARN, AAI, and AAN), the effects of the manufacturer's altruistic preference on decisions are as follows:*

(1) *The GL satisfies* $\partial e^{ARI}/\partial\theta_m = \partial e^{ARN}/\partial\theta_m = \partial e^{AAI}/\partial\theta_m = \partial e^{AAN}/\partial\theta_m = 0$.

(2) *The wholesale prices in the first and second periods satisfy* $\partial w_1^{ARI}/\partial\theta_m < 0, \partial w_2^{ARI}/\partial\theta_m < 0$, $\partial w_1^{AAI}/\partial\theta_m < 0, \partial w_2^{AAI}/\partial\theta_m < 0$, $\partial w_1^{AAN}/\partial\theta_m = \partial w_2^{AAN}/\partial\theta_m < 0$, *and* $\partial w_1^{ARN}/\partial\theta_m = \partial w_2^{ARN}/\partial\theta_m < 0$.

(3) *The selling prices in the first and second periods meet* $\partial p_1^{ARI}/\partial\theta_m < 0, \partial p_2^{ARI}/\partial\theta_m < 0$, $\partial p_1^{AAI}/\partial\theta_m < 0$, $\partial p_2^{AAI}/\partial\theta_m < 0$, $\partial p_1^{AAN}/\partial\theta_m = \partial p_2^{AAN}/\partial\theta_m < 0$, *and* $\partial p_1^{ARN}/\partial\theta_m = \partial p_2^{ARN}/\partial\theta_m < 0$.

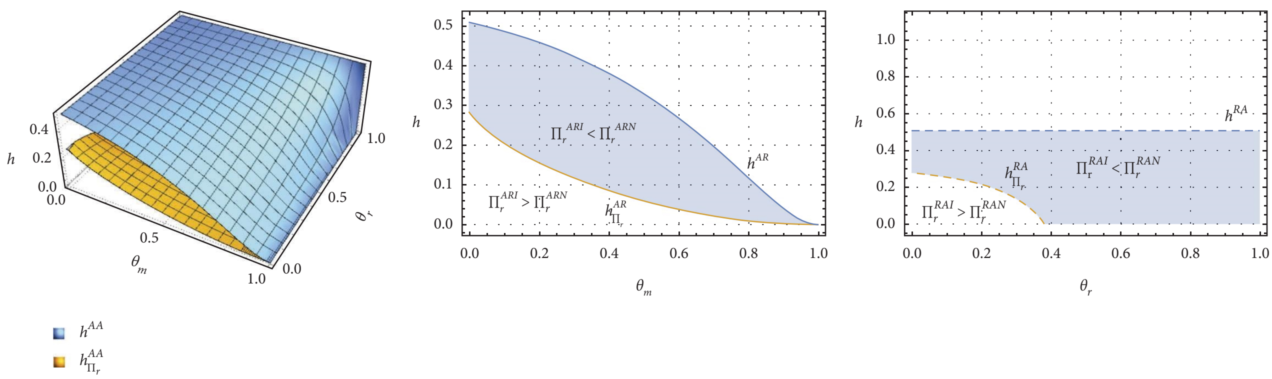
(4) *The manufacturer's altruistic preference promotes an increase in the second-period ordering quantities. The influence of the manufacturer's altruistic preference on the first-period ordering quantities is affected by the purchasing strategy adopted.*

(5) *The retailer's inventory does not change monotonously with the manufacturer's altruism. Further details are shown in Table 7.*

Through calculation, it can be found that, for MIGPs, the manufacturer's altruism still does not affect the GL. The manufacturer's altruistic preference promotes the reduction of his wholesale prices, so the retailer also reduces selling prices and increases sale quantities. For the retailer without strategic inventory, the decrease in wholesale prices promotes an increase in order quantities. However, for the retailer with strategic inventory, the effect of the manufacturer's altruism on retailer's order quantities and inventories in the first period is not monotonous. The thresholds are as shown in Figures 10(a) and 10(b). When $0 < h < h_{mQ_1}^{AA}$, $(\partial Q_1^{AAI}/\partial\theta_m) > 0$; when $h_{mQ_1}^{AA} < h < h^{AA}$, $\partial Q_1^{AAI}/\partial\theta_m < 0$; when $0 < h < h_{mI}^{AA}$, $(\partial I^{AAI}/\partial\theta_m) > 0$; and when $h_{mI}^{AA} < h < h^{AA}$, $\partial I^{AAI}/\partial\theta_m < 0$. Scenario ARI is similar to scenario AAI.

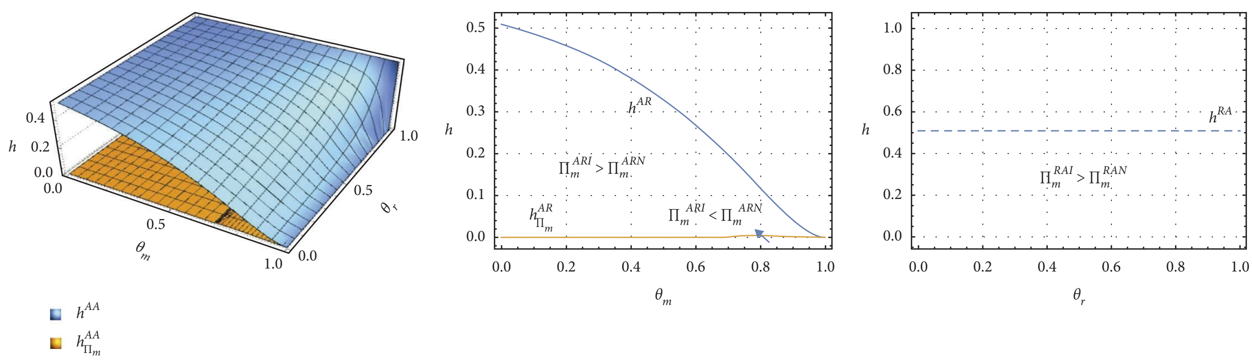
Proposition 8. *In four scenarios (ARI, ARN, AAI, and AAN), the manufacturer's altruistic preference increases the profits of the retailer and supply chain and reduces his profits.*

As shown in Figures 11(a)–11(d), the effects of the manufacturer's altruistic preference on his, the retailer's, and the supply chain's profits are consistent across the four scenarios. The results also show that the manufacturer's altruistic preference has a greater impact on the retailer's profits than on the manufacturer's profits. This is significantly different from what is observed under the



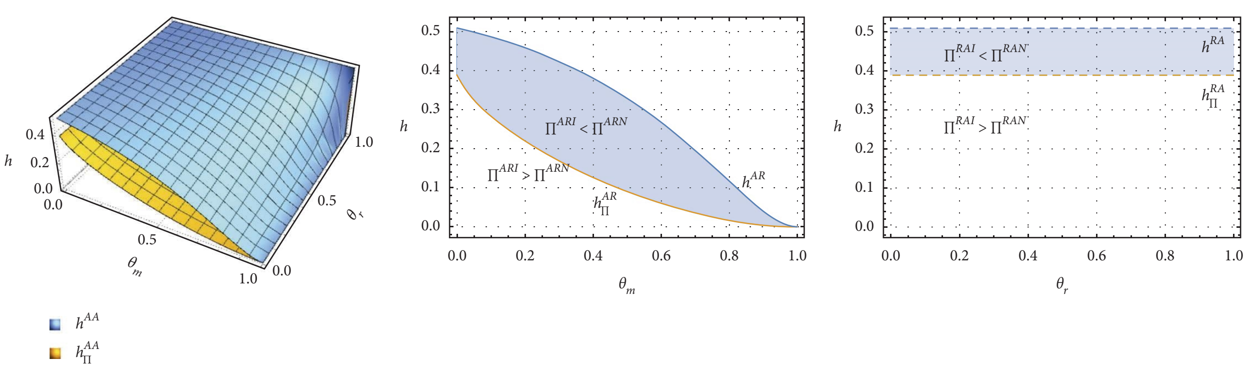
(a) (b) (c)

FIGURE 4: Thresholds of the retailer's profits for different altruistic scenarios $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) Both members are altruistic. (b) Only the manufacturer is altruistic. (c) Only the retailer is altruistic.



(a) (b) (c)

FIGURE 5: Thresholds of the manufacturer's profits for different altruistic scenarios $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) Both members are altruistic. (b) Only the manufacturer is altruistic. (c) Only the retailer is altruistic.



(a) (b) (c)

FIGURE 6: Thresholds of the supply chain's profits for different altruistic scenarios $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) Both members are altruistic. (b) Only the manufacturer is altruistic. (c) Only the retailer is altruistic.

differentiation scenario, in which the retailer's altruistic preference has an inconsistent impact on supply chain profits.

In general, it can be found that (1) decision makers' simultaneous or individual altruistic preferences may have different impacts on the selection of strategies and decision-making. For example, when only the retailer is altruistic, this does not affect procurement strategies. However, when both decision-makers exhibit altruism, the retailer's altruism expands the range of strategic inventory that can be held. (2) Diverging from Huang et al. [14], our results show altruistic preferences do not affect the greening level, demonstrating

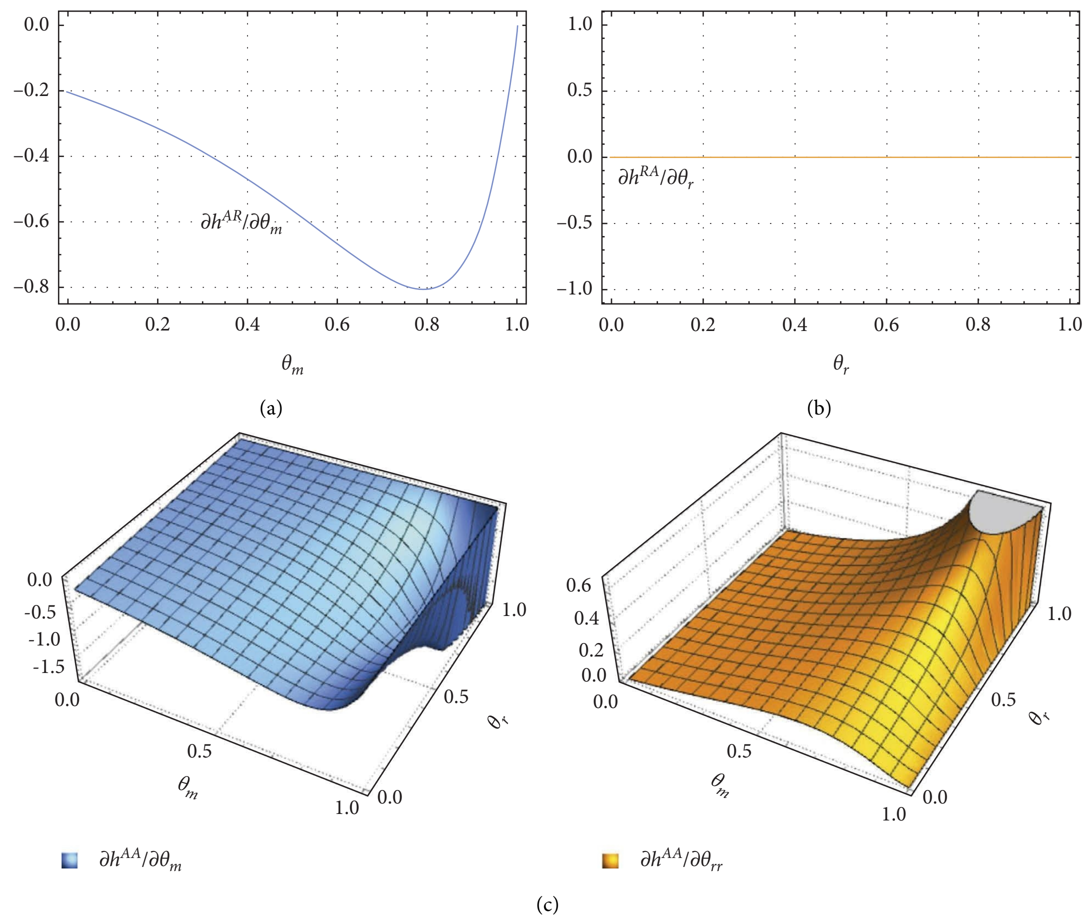


Figure 7: Influence of different members' altruistic preferences on the range of strategic inventory $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) Only the manufacturer is altruistic. (b) Only the retailer is altruistic. (c) Both members are altruistic.

Table 6: Influence of the retailer's altruistic preference on decisions.

	e	w_1	Q_1	I	q_1	p_1	w_2	Q_2	q_2	p_2
RAI	–	↗	–	–	–	–	↗	–	–	–
AAI	–	↗	*	*	↘	↗	↗	↘	↘	↗
RAN	–	↗	–		–	–	↗	–	–	–
AAN	–	↗	↘		↘	↗	↗	↘	↘	↗

"–" indicates that variables are not affected by θ_r. "↗" represents that variables increase with an increasing θ_r. "↘" indicates that variables decrease with an increasing θ_r. "*" indicates that the change in variables with θ_r is not monotonic.

the importance of subdividing green product categories. (3) In terms of supply chain profits, the retailer's altruistic preference does not increase profits of the overall green supply chain, while the manufacturer's altruism has the opposite impact.

6. Conclusion

With the continuous improvement of consumers' environmental awareness and the refinement of green product design, products' greening levels and differentiated purchasing strategies impact multiperiod decisions and profits. For retailers who are followers, strategic inventory is commonly used as a bargaining tool. Most of the previous strategic inventory models assume that supply chain members are rational. However, in reality, more and more enterprises are exhibiting altruistic preferences to promote the industry's development. Therefore, this paper constructs two-period game models considering six scenarios and further analyzes the impact of altruistic preference on green supply chain decision-making and benefits.

This study presents some interesting results. (1) For MIGPs, strategic inventory and altruistic preference do not affect the GL. Therefore, promoting the transformation of MIGPs into DIGPs is a top priority. (2) In different scenarios, the retailer holding strategic inventory does not necessarily secure higher profits, and the manufacturer may not obtain profits from strategic inventory. (3) The manufacturer's altruism reduces the range of strategic inventory

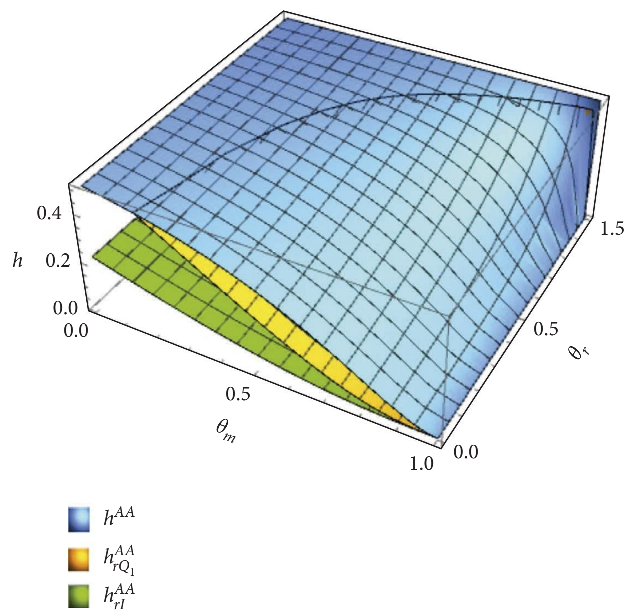


FIGURE 8: Thresholds of retailer altruism's influence on first-period ordering quantities and inventories $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$.

that the retailer can hold, but the effect on inventory quantity is nonmonotonic. However, the influence of retailers' altruistic preferences on nonsingle-period procurement strategies is related to other members' behavior preferences. (4) The influence of the retailer's altruistic preferences on her decision-making is significantly different in various scenarios. For example, when only the retailer is altruistic, the range of strategic inventory is not affected by altruism. When both supply chain members are altruistic, the range of strategic inventory increases with the retailer's altruistic preference. (5) The retailer's altruism does not necessarily affect the green supply chain's profits, but the manufacturer's altruistic preference increases the green supply chain's profits.

In addition to the theoretical conclusions, through calculation and comparison, this study can also put forward some management guidance: (1) from an environmental perspective, the impact of environmental protection publicity or education in areas with high consumption levels on the greening level of MIGPs is greater than that of market demand. (2) This study finds that even when supply chain members are altruistic, strategic inventory, as a non-single period procurement strategy, may have a negative impact. According to previous research considering rational decision-makers, strategic inventory not only brings more bargaining space for retailers but also enables strong income growth for manufacturers as a means of long-term cooperation [9, 11]. However, in green supply chains, as partners are not entirely rational, whether long-term partnerships can bring greater benefits to the partners themselves, participants, and even the whole supply chain needs to be further considered and discussed among enterprises. (3) Compared to manufacturers, retailers acting as followers should pay more attention to the behavior preferences of other decision-makers. In the green supply chain, whether only the retailer exhibits altruism dramatically affects long-term procurement strategies and decision-making. (4) Unlike Huang et al. [14], this research does not find altruism to affect the greening level of products. This requires manufacturers to clarify the design differences of green products and subdivide categories. Since many governments and institutions subsidize green supply chains, whether altruism has a positive impact on the development of green products or the supply chain also requires more attention from governments, especially in consideration of different types of green products and the status of subsidized members in the industry.

This study can be further expanded by considering other important factors. First, because this research focuses on MIGPs, differentiated green design products can be further discussed, such as DIGPs and MDIGPs. Second, this paper mainly considers two procurement methods: holding and not holding strategic inventory. In reality, retailers are likely to purchase products needed in the first period. Therefore, the different procurement and cooperation modes discussed may also provide further insight. Finally, as this analysis only focuses on the impact of altruistic preferences in the manufacturer-led green supply chain, other behavior and psychological factors can be introduced into future models.

Appendix

A. Detailed Derivation of the Optimal Solution

A.1. Detailed Derivation of the Optimal Solution in Scenario AAI. The optimal solution for the retailer second-period optimization problem presented in equation (1) can be obtained by solving $dU_{r2}^{AAI}/dp_2^{AAI} = 0$. And, the retailer's utility function in period 2 is concave because

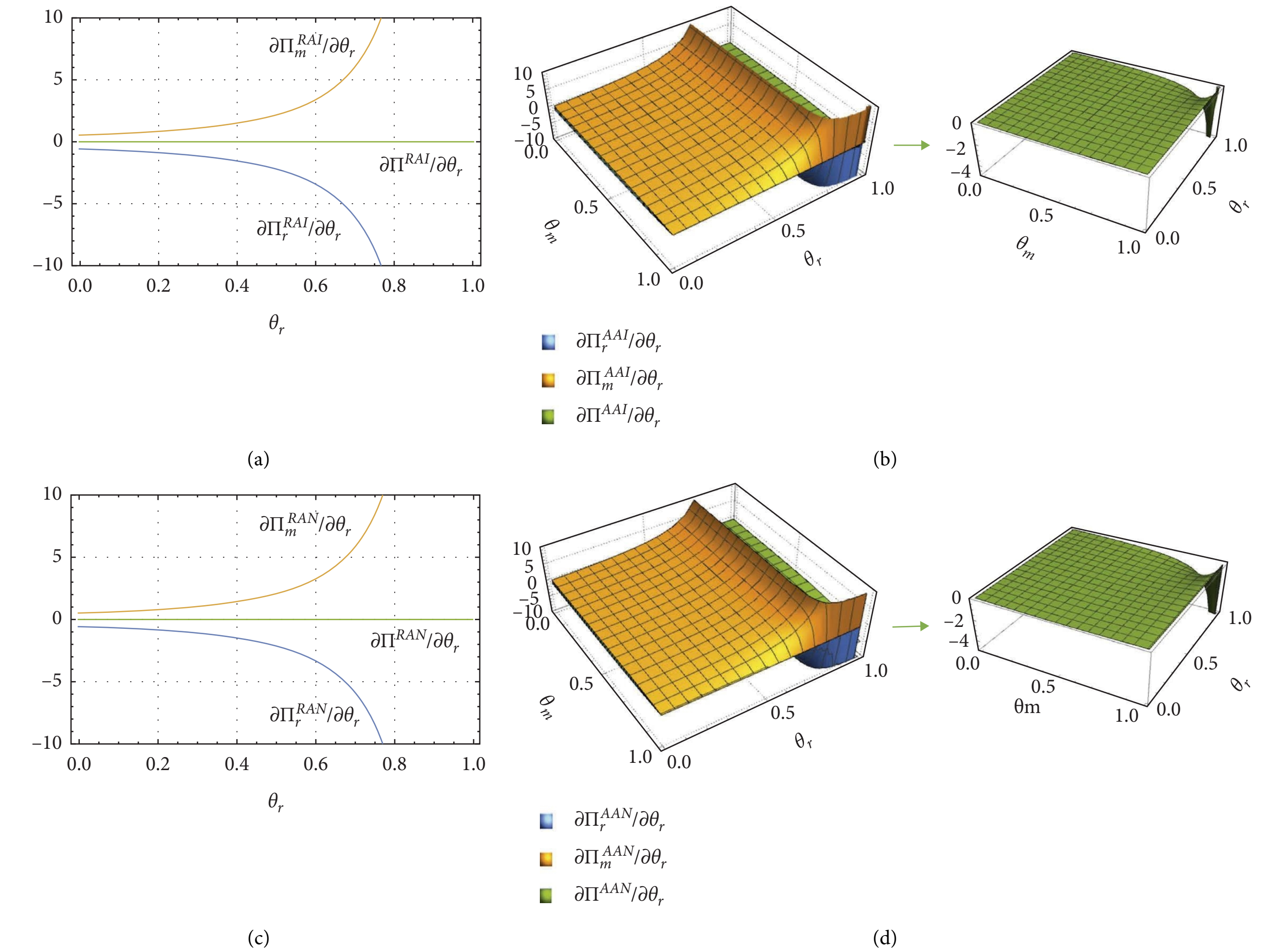


FIGURE 9: Influence of the retailer's altruistic preference on profits $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) In scenario RAI. (b) In scenario AAI. (c) In scenario RAN. (d) In scenario AAN.

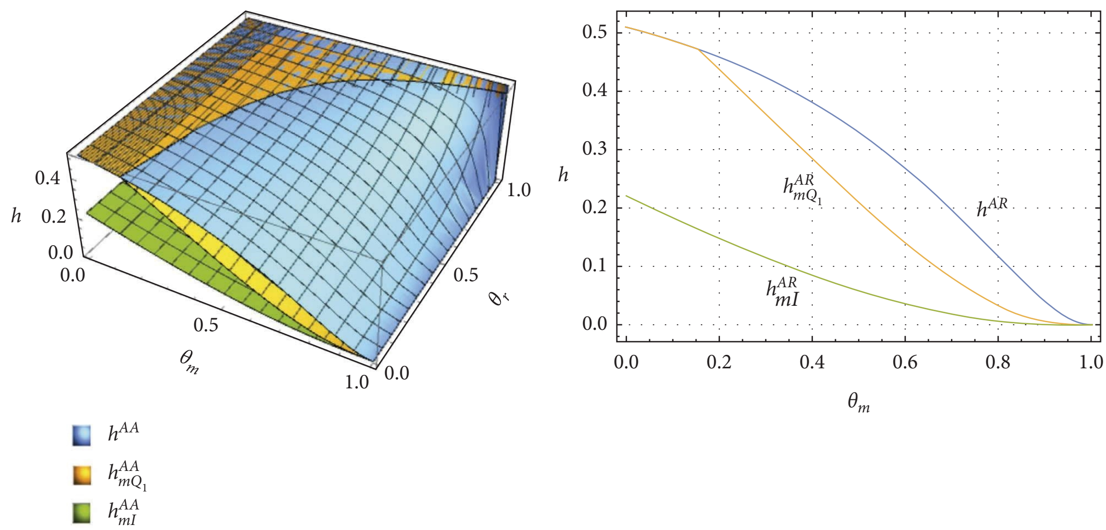
TABLE 7: Influence of manufacturers' altruistic preferences on decisions.

	e	w_1	Q_1	I	q_1	p_1	w_2	Q_2	q_2	p_2
ARI	–	↘	*	*	↗	↘	↘	↗	↗	↘
AAI	–	↘	*	*	↗	↘	↘	↗	↗	↘
ARN	–	↘	↗		↗	↘	↘	↗	↗	↘
AAN	–	↘	↗		↗	↘	↘	↗	↗	↘

$d^2U_{r2}^{AAI}/dp_2^{AAI^2} = -2b < 0$. So, the retailer's second-period optimal selling price is $p_2^{AAI} = (a + ce^{AAI} + b(w_2^{AAI} - \theta_r w_2^{AAI} + e^{AAI^2}\theta_r\gamma))/(2b)$.

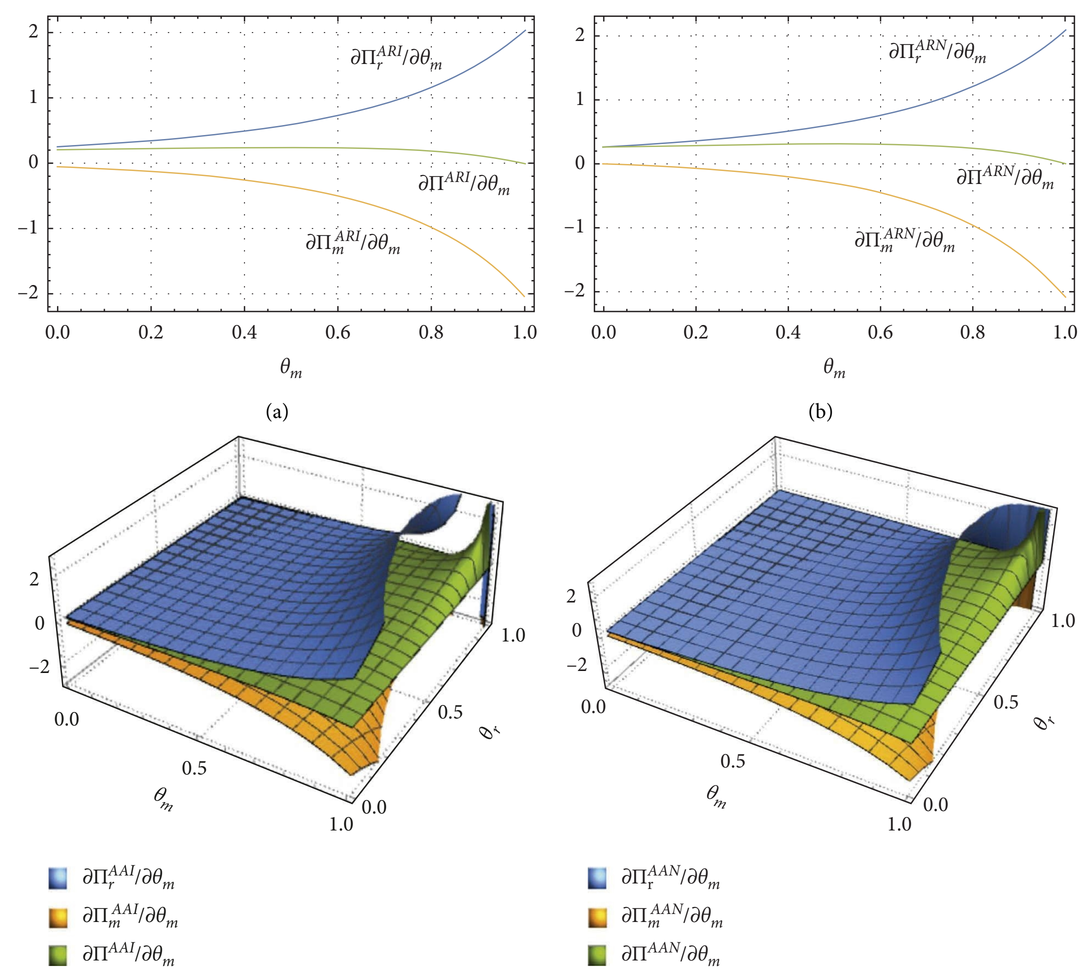
Substituting the retailer's optimal response in equation (2), the second-period wholesale price can be obtained by solving $dU_{m2}^{AAI}/dw_2^{AAI} = 0$. And, the manufacturer's utility function in period 2 is concave because $d^2U_{m2}^{AAI}/dw_2^{AAI^2} = -b(-1 + \theta_r)(-2 + \theta_m + \theta_r\theta_m)/2 < 0$. So, the optimal second-period wholesale price is $w_2^{AAI} = (a - 2I^{AAI} - a\theta_m + 2I^{AAI}\theta_m + c(e^{AAI} - e^{AAI}\theta_m) + e^{AAI^2}(b\gamma - 2b\theta_r\gamma + b\theta_r^2\theta_m\gamma))/(b(-1 + \theta_r)(-2 + \theta_m + \theta_r\theta_m))$.

Substituting optimal response of the manufacturer in equation (3), the selling price and inventory can be obtained by solving $\partial U_r^{AAI}/\partial p_1^{AAI} = 0$ and $\partial U_r^{AAI}/\partial I^{AAI} = 0$. And, the retailer's utility function is concave because $\partial^2 U_r^{AAI}/\partial p_1^{AAI^2} = -2b < 0$ and $(\partial^2 U_r^{AAI}/\partial p_1^{AAI^2}) * (\partial^2 U_r^{AAI}/\partial I^{AAI^2}) - (\partial^2 U_r^{AAI}/\partial p_1^{AAI}\partial I^{AAI})^2 = (4(-1 + \theta_m)(-3 + \theta_m + 2\theta_r\theta_m))/(-2 + \theta_m + \theta_r\theta_m)^2 > 0$. So, the retailer's



(a) (b)

FIGURE 10: Thresholds of manufacturer altruism's influence on first-period order quantities and inventories $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) In scenario AAI. (b) In scenario ARI.



(c) (d)

FIGURE 11: Influence of the manufacturer's altruistic preference on profits $(a = 1, b = 0.5, c = 0.2, \gamma = 1)$. (a) In scenario ARI. (b) In scenario ARN. (c) In scenario AAI. (d) In scenario AAN.

first-period optimal selling price is $p_1^{AAI} = (a + ce^{AAI} + b(w_1^{AAI} - \theta_r w_1^{AAI} + e^{AAI^2}\theta_r\gamma))/(2b)$, and strategic inventory quantity is

$$I^{AAI} = \frac{\left(\left(a + ce^{AAI}\right)(-1+\theta_m)(-3+\theta_m+2\theta_r\theta_m) - b\begin{pmatrix} h(-2+\theta_m+\theta_r\theta_m)^2 - (-1+\theta_r)(-2+\theta_m+\theta_r\theta_m)^2 w_1^{AAI} + \\ e^{AAI^2}\left(-1+\theta_r^2(-4+\theta_m)\theta_m + \theta_r^3\theta_m^2 + \theta_r\left(4-2\theta_m+\theta_m^2\right)\right)\gamma \end{pmatrix}\right)}{\left(2(-1+\theta_m)(-3+\theta_m+2\theta_r\theta_m)\right)}. \tag{A.1}$$

Finally, substituting the retailer's optimal response in equation (4), the first-period wholesale price and GL can be obtained by solving $\partial U_m^{AAI}/\partial w_1^{AAI} = 0$ and $\partial U_m^{AAI}/\partial e^{AAI} = 0$. We can obtain three sets of solutions satisfying the conditions:

The first set:

$$\left(w_1^{AAI}, e^{AAI}\right) = \left(\frac{\begin{pmatrix} c^2(-1+\theta_m)\begin{pmatrix} 52 - 71\theta_m + 30\theta_m^2 - 4\theta_m^3 + 7\theta_r^4\theta_m^3 + 4\theta_r^3\theta_m^2(-9+2\theta_m) + \\ \theta_r^2\theta_m\left(61 - 6\theta_m - 13\theta_m^2\right) - 2\theta_r\left(17 + 22\theta_m - 33\theta_m^2 + 8\theta_m^3\right)\end{pmatrix} - \\ 4b\begin{pmatrix} 2a(-1+\theta_m)^2(-3+\theta_m+2\theta_r\theta_m)^2 + bh(-2+\theta_m+\theta_r\theta_m)^2 * \\ \left(-1 - 2(-2+\theta_r)\theta_m + \left(-1 - 2\theta_r + 2\theta_r^2\right)\theta_m^2\right)\end{pmatrix}\end{pmatrix}\gamma}{4b^2(-1+\theta_r)(-1+\theta_m)\left(-34 + (41+61\theta_r)\theta_m - 2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2 + \left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)\gamma}, \frac{c}{2b\gamma}\right). \tag{A.2}$$

The second set:

$$\left(w_1^{AAI}, e^{AAI}\right) = \left(\frac{c^2(-1+\theta_m)B_2 + b\left(2a(-1+\theta_m)B_2 + bh\left(8 - 2(12+5\theta_r)\theta_m + \left(15+26\theta_r+3\theta_r^2\right)\theta_m^2 - \left(3+8\theta_r+7\theta_r^2\right)\theta_m^3\right)\right)\gamma + c(-1+\theta_m)B_1}{2b^2(-1+\theta_m)B_2\gamma}, \frac{cB_2 + B_1}{2bB_2\gamma}\right). \tag{A.3}$$

The third set:

$$\left(w_1^{AAI}, e^{AAI}\right) = \left(\frac{c^2(-1+\theta_m)B_2 + b\left(2a(-1+\theta_m)B_2 + bh\left(8 - 2(12+5\theta_r)\theta_m + \left(15+26\theta_r+3\theta_r{}^2\right)\theta_m{}^2 - \left(3+8\theta_r+7\theta_r{}^2\right)\theta_m{}^3\right)\right)\gamma - c(-1+\theta_m)B_1}{2b^2(-1+\theta_m)B_2\gamma}, \frac{cB_2 - B_1}{2bB_2\gamma}\right). \tag{A.4}$$

To verify optimality, we compute the following:

$$\frac{\partial^2 U_m^{AAI}}{\partial w_1^{AAI^2}} = -\frac{b(-1+\theta_r)\left(-34 + (41+61\theta_r)\theta_m - 2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2 + \left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)}{2(-3+\theta_m+2\theta_r\theta_m)^2} < 0, \tag{A.5}$$

$$
\begin{aligned}
\Delta_1 &= \frac{\partial^2 U_m^{AAI}}{\partial w_1^{AAI^2}} * \frac{\partial^2 U_m^{AAI}}{\partial e^{AAI^2}} - \left(\frac{\partial^2 U_m^{AAI}}{\partial w_1^{AAI}\partial e^{AAI}}\right)^2 \\
&= \frac{1}{4\left(-3+\theta_m+2\theta_r\theta_m\right)^4}\left(\begin{array}{c}
-4\left(\begin{array}{c} c\left(-1+\theta_m\right)\left(-3+\theta_m+2\theta_r\theta_m\right)^2 - be^{AAI} * \\ \left(\begin{array}{c} 16-11\theta_m+2\theta_m^2+7\theta_r^4\theta_m^3+4\theta_r^2\theta_m^2\left(-9+2\theta_m\right)+ \\ 2\theta_r\left(-17+2\theta_m+\theta_m^2\right)+\theta_r^2\theta_m\left(61-22\theta_m+3\theta_m^2\right)\end{array}\right)\gamma \end{array}\right)^2 + \\
\left(2/\left(-1+\theta_m\right)\right)\left(-1+\theta_r\right)\left(\begin{array}{c} -34+\left(41+61\theta_r\right)\theta_m - 2*\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2 + \\ \left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3 \end{array}\right) * \\
\left(\begin{array}{c}
-c^2\left(-1+\theta_m\right)\theta_m\left(-3+\theta_m+2\theta_r\theta_m\right)^2 + 6bce^{AAI}\left(-1+\theta_m\right) * \\
\left(-3+\theta_m+2\theta_r\theta_m\right)^2\gamma + b\gamma\left(\begin{array}{c}
2a\left(-1+\theta_m\right)\left(-3+\theta_m+2\theta_r\theta_m\right)^2 - \\
b\left(\begin{array}{c}
h\left(\begin{array}{c} -4+\left(11-t4n\theta_r\right)\theta_m+3*\left(-2-2\theta_r+5\theta_r^2\right)\theta_m^2+\left(1+2\theta_r-4\theta_r^2-10\theta_r^3\right)* \\ \theta_m^3+\theta_r^2\left(1+2\theta_r+2\theta_r^2\right)\theta_m^4 \end{array}\right)+ \\
\left(-1+\theta_m\right)\left(\begin{array}{c}
\left(16-11\theta_m+2\theta_m^2+7\theta_r^4\theta_m^3+4\theta_r^3\theta_m^2*\left(-9+2\theta_m\right)+2\theta_r\left(-17+2\theta_m+\theta_m^2\right)+\theta_r^2\theta_m\left(61-22\theta_m+3\theta_m^2\right)\right)w_1^{AAI} - \\
3e^{AAI^2}\left(\begin{array}{c} -2+\theta_m+7\theta_r^4\theta_m^3+4\theta_r^3\theta_m^2*\left(-9+2\theta_m\right)+ \\ \theta_r\left(-34+28\theta_m-6\theta_m^2\right)+\theta_r^2\theta_m\left(61-30\theta_m+3\theta_m^2\right)\end{array}\right)\gamma
\end{array}\right)
\end{array}\right)
\end{array}\right)
\end{array}\right)
\end{array}\right).
\end{aligned}
\tag{A.6}
$$

By calculating, the manufacturer's utility function is concave at the first set of solutions, but it cannot satisfy $\Delta_1 > 0$, $w_1^{AAI} > 0$, and $e^{AAI} > 0$ in the second and third sets. Therefore, we can obtain that when $h < h^{AA} = ((-1+\theta_m)^2(5-2(1+4\theta_r)\theta_m+\theta_r(2+3\theta_r){\theta_m}^2)(c^2+4ab\gamma))/(4b^2(-2+\theta_m+\theta_r\theta_m)^2(5-5(1+\theta_r)\theta_m+(1+3\theta_r+{\theta_r}^2)\ {\theta_m}^2)\gamma)$, the retailer can choose to hold strategic inventory.

$$
\begin{aligned}
B_1 &= \sqrt{\left(\left(18-2(7+11\theta_r)\theta_m+\left(3+8\theta_r+7{\theta_r}^2\right){\theta_m}^2\right)\left(\begin{array}{c} c^2\left(18-2(7+11\theta_r)\theta_m+\left(3+8\theta_r+7\theta_r^2\right)\theta_m^2\right) \\ +2b\left(-bh\left(8-2(3+5\theta_r)\theta_m+\left(1+4\theta_r+3\theta_r^2\right)\theta_m^2\right)+2a\left(18-2(7+11\theta_r)\theta_m+\left(3+8\theta_r+7\theta_r^2\right)\theta_m^2\right)\right)\gamma \end{array}\right)\right)} \\
B_2 &= \left(18-2(7+11\theta_r)\theta_m+\left(3+8\theta_r+7\theta_r^2\right)\theta_m^2\right)
\end{aligned}
\tag{A.7}
$$

A.2. Detailed Derivation of the Optimal Solution in Scenario AAN. The solution for the retailer optimization problem presented in equation (5) can be obtained by solving $dU_{r1}^{AAN}/dp_1^{AAN} = 0$. And, the retailer's utility function in the first period is concave because $d^2U_{r1}^{AAN}/dp_1^{AAN^2} = -2b < 0$. So, the retailer's first-period optimal selling price is $p_1^{AAN} = (a + ce^{AAN} + b(w_1^{AAN} - \theta_r w_1^{AAN} + e^{AAN^2}\theta_r\gamma))/(2b)$.

Substituting the retailer's optimal response in equation (6), the first-period wholesale price and GL can be obtained by solving $\partial U_{m1}^{AAN}/\partial w_1^{AAN} = 0$ and $\partial U_{m1}^{AAN}/\partial e^{AAN} = 0$. We can obtain three sets of solutions satisfying the conditions:

The first set: $(w_1^{AAN}, e^{AAN}) = ((c^2(3-2\theta_r - 2\theta_m + \theta_r^2\theta_m) - 4ab(-1+\theta_m)\gamma)/(4b^2(-1+\theta_r)(-2+\theta_m+\theta_r\theta_m)\gamma), c/(2b\gamma))$.

The second set: $(w_1^{AAN}, e^{AAN}) = ((c^2 + 2ab\gamma - c\sqrt{c^2+4ab\gamma})/(2b^2\gamma), (c - \sqrt{c^2+4ab\gamma})/(2b\gamma))$.

The third set: $(w_1^{AAN}, e^{AAN}) = ((c^2 + 2ab\gamma + c\sqrt{c^2+4ab\gamma})/\ (2b^2\gamma), (c + \sqrt{c^2+4ab\gamma})/(2b\gamma))$.

To verify optimality, we compute the following:

$$
\frac{\partial^2 U_{m1}^{AAN}}{\partial w_1^{AAN^2}} = -\frac{1}{2}b(-1+\theta_r)(-2+\theta_m+\theta_r\theta_m) < 0,
\tag{A.8}
$$

$$
\Delta_2 = \frac{\partial^2 U_{m1}^{AAN}}{\partial w_1^{AAN\,2}} * \frac{\partial^2 U_{m1}^{AAN}}{\partial e^{AAN^2}} - \left(\frac{\partial^2 U_{m1}^{AAN}}{\partial w_1^{AAN}\partial e^{AAN}}\right)^2 = \frac{1}{4}\left(\begin{array}{c} -\left(c(-1+\theta_m) - 2be^{AAN}\left(1-2\theta_r+\theta_r^2\theta_m\right)\gamma\right)^2 + (-1+\theta_r)(-2+\theta_m+\theta_r\theta_m) \\ \left(-c^2\theta_m + 6bce^{AAN}\gamma + 2b\gamma\left(a - b\left(\left(1-2\theta_r+\theta_r^2\theta_m\right)w_1^{AAN} - 3e^{AAN^2}\theta_r(-2+\theta_r\theta_m)\gamma\right)\right)\right)\end{array}\right).
\tag{A.9}
$$

By calculating, the manufacturer's utility function is concave at the first set of solutions, but it cannot satisfy $\Delta_2 > 0$, $w_1^{AAN} > 0$, and $e^{AAN} > 0$ in the second and third sets.

B. Proofs

Proof of Proposition 3.

To explore the impact of strategic inventory, we compare the differences of equilibrium solutions under different altruistic scenarios (AA, AR, and RA).

(1) The influence of strategic inventory on manufacturer's decisions:

For GL, $e^{AAI} - e^{AAN} = 0$; $e^{ARI} - e^{ARN} = 0$; $e^{RAI} - e^{RAN} = 0$.

For first-period wholesale prices,

$$\begin{aligned} w_1^{AAI} - w_1^{AAN} &= -\frac{c^2(-1+\theta_m)^2(-1+\theta_r\theta_m)^2 + 4b\left(a(-1+\theta_m)^2(-1+\theta_r\theta_m)^2 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(-1-2(-2+\theta_r)\theta_m + \left(-1-2\theta_r+2\theta_r^2\right)\theta_m^2\right)\right)\gamma}{4b^2(-1+\theta_r)(-1+\theta_m)(-2+\theta_m+\theta_r\theta_m)\left(17-2(6+11\theta_r)\theta_m + \left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)\gamma} > 0,\\ w_1^{ARI} - w_1^{ARN} &= \frac{c^2(-1+\theta_m)^2 + 4b\left(a(-1+\theta_m)^2 - bh(-2+\theta_m)^2\left(1-4\theta_m+\theta_m^2\right)\right)\gamma}{4b^2(-2+\theta_m)(-1+\theta_m)\left(17-12\theta_m+2\theta_m^2\right)\gamma} > 0,\\ w_1^{RAI} - w_1^{RAN} &= -\frac{c^2+4b(a-4bh)\gamma}{136b^2(-1+\theta_r)\gamma} > 0. \end{aligned} \tag{B.1}$$

For second-period wholesale prices,

$$w_2^{AAI} - w_2^{AAN} = \frac{c^2(-1+\theta_m)^2C_1 - 4b\left(-a(-1+\theta_m)^2\left(C_1 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(5-5(1+\theta_r)\theta_m + \left(1+3\theta_r+\theta_r^2\right)\theta_m^2\right)\right)\gamma\right)}{4b^2(-1+\theta_r)(-1+\theta_m)(-2+\theta_m+\theta_r\theta_m)\left(17-2(6+11\theta_r)\theta_m + \left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)\gamma} < 0, \tag{B.2}$$

$$\begin{aligned} w_2^{ARI} - w_2^{ARN} &= \frac{c^2(-1+\theta_m)^2(-5+2\theta_m) + 4b\left(a(-1+\theta_m)^2(-5+2\theta_m) + bh(-2+\theta_m)^2\left(5-5\theta_m+\theta_m^2\right)\right)\gamma}{4b^2\left(34-75\theta_m+57\theta_m^2-18\theta_m^3+2\theta_m^4\right)\gamma} < 0,\\ w_2^{RAI} - w_2^{RAN} &= \frac{5\left(c^2+4b(a-4bh)\gamma\right)}{136b^2(-1+\theta_r)\gamma} < 0. \end{aligned} \tag{B.3}$$

(2) The effect of strategic inventory on retailer's decisions:

For second-period ordering quantities,

$$Q_2^{AAI} - Q_2^{AAN} = \frac{(-1+\theta_r\theta_m)\left(-c^2(-1+\theta_m)^2C_1 + 4b\left(-a(-1+\theta_m)^2C_1 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(5-5(1+\theta_r)\theta_m + \left(1+3\theta_r+\theta_r^2\right)\theta_m^2\right)\right)\gamma\right)}{8b(-1+\theta_m)^2(-2+\theta_m+\theta_r\theta_m)\left(17-2(6+11\theta_r)\theta_m + \left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)\gamma} < 0, \tag{B.4}$$

$$\begin{aligned} Q_2^{ARI} - Q_2^{ARN} &= -\frac{c^2(-1+\theta_m)^2(-5+2\theta_m) + 4b\left(a(-1+\theta_m)^2(-5+2\theta_m) + bh(-2+\theta_m)^2\left(5-5\theta_m+\theta_m^2\right)\right)\gamma}{8b(-1+\theta_m)^2\left(-34+41\theta_m-16\theta_m^2+2\theta_m^3\right)\gamma} < 0,\\ Q_2^{RAI} - Q_2^{RAN} &= -\frac{5\left(c^2+4b(a-4bh)\gamma\right)}{272b\gamma} < 0. \end{aligned} \tag{B.5}$$

For first-period selling prices,

$$p_1^{AAI} - p_1^{AAN} = \frac{c^2(-1+\theta_m)^2(-1+\theta_r\theta_m)^2 + 4b\left(a(-1+\theta_m)^2(-1+\theta_r\theta_m)^2 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(-1-2(-2+\theta_r)\theta_m + \left(-1-2\theta_r+2\theta_r^2\right)\theta_m^2\right)\right)\gamma}{8b^2(-1+\theta_m)\left(-34+(41+61\theta_r)\theta_m - 2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2 + \left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)\gamma} > 0, \tag{B.6}$$

$$\begin{aligned} p_1^{ARI} - p_1^{ARN} &= \frac{c^2(-1+\theta_m)^2 + 4b\left(a(-1+\theta_m)^2 - bh(-2+\theta_m)^2\left(1-4\theta_m+\theta_m^2\right)\right)\gamma}{8b^2\left(34-75\theta_m+57\theta_m^2-18\theta_m^3+2\theta_m^4\right)\gamma} > 0, \\ p_1^{RAI} - p_1^{RAN} &= \frac{c^2+4b(a-4bh)\gamma}{272b^2\gamma} > 0. \end{aligned} \tag{B.7}$$

For second-period selling prices,

$$p_2^{AAI} - p_2^{AAN} = \frac{-c^2(-1+\theta_m)^2 C_1 + 4b\left(-a(-1+\theta_m)^2 C_1 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(5-5(1+\theta_r)\theta_m + \left(1+3\theta_r+\theta_r^2\right)\theta_m^2\right)\right)\gamma}{8b^2(-1+\theta_m)(-2+\theta_m+\theta_r\theta_m)\left(17-2(6+11\theta_r)\theta_m + \left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)\gamma} < 0, \tag{B.8}$$

$$\begin{aligned} p_2^{ARI} - p_2^{ARN} &= \frac{c^2(-1+\theta_m)^2(-5+2\theta_m) + 4b\left(a(-1+\theta_m)^2(-5+2\theta_m) + bh(-2+\theta_m)^2\left(5-5\theta_m+\theta_m^2\right)\right)\gamma}{8b^2\left(34-75\theta_m+57\theta_m^2-18\theta_m^3+2\theta_m^4\right)\gamma} < 0, \\ p_2^{RAI} - p_2^{RAN} &= -\frac{5\left(c^2+4b(a-4bh)\gamma\right)}{272b^2\gamma} < 0. \end{aligned} \tag{B.9}$$

For first-period selling quantities,

$$q_1^{AAI} - q_1^{AAN} = -\frac{c^2(-1+\theta_m)^2(-1+\theta_r\theta_m)^2 + 4b\left(a(-1+\theta_m)^2(-1+\theta_r\theta_m)^2 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(-1-2(-2+\theta_r)\theta_m + \left(-1-2\theta_r+2\theta_r^2\right)\theta_m^2\right)\right)\gamma}{8b(-1+\theta_m)\left(-34+(41+61\theta_r)\theta_m - 2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^3 + \left(2+10\theta_r+15\theta_r^2+7\theta_r^2\right)\theta_m^3\right)\gamma} < 0, \tag{B.10}$$

$$\begin{aligned} q_1^{ARI} - q_1^{ARN} &= -\frac{c^2(-1+\theta_m)^2 + 4b\left(a(-1+\theta_m)^2 - bh(-2+\theta_m)^2\left(1-4\theta_m+\theta_m^2\right)\right)\gamma}{8b(-2+\theta_m)(-1+\theta_m)\left(17-12\theta_m+2\theta_m^2\right)\gamma} < 0, \\ q_1^{RAI} - q_1^{RAN} &= \frac{1}{272}\left(-4a+16bh-\frac{c^2}{b\gamma}\right) < 0. \end{aligned} \tag{B.11}$$

For second-period selling quantities,

$$q_2^{AAI} - q_2^{AAN} = \frac{c^2(-1+\theta_m)^2 C_1 - 4b\left(-a(-1+\theta_m)^2 C_1 + bh(-2+\theta_m+\theta_r\theta_m)^2\left(5-5(1+\theta_r)\theta_m + \left(1+3\theta_r+\theta_r^2\right)\theta_m^2\right)\right)\gamma}{8b(-1+\theta_m)(-2+\theta_m+\theta_r\theta_m)\left(17-2(6+11\theta_r)\theta_m + \left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)\gamma} > 0, \tag{B.12}$$

$$\begin{aligned} q_2^{ARI} - q_2^{ARN} &= -\frac{c^2(-1+\theta_m)^2(-5+2\theta_m) + 4b\left(a(-1+\theta_m)^2(-5+2\theta_m) + bh(-2+\theta_m)^2\left(5-5\theta_m+\theta_m^2\right)\right)\gamma}{8b(-2+\theta_m)(-1+\theta_m)\left(17-12\theta_m+2\theta_m^2\right)\gamma} > 0, \\ q_2^{RAI} - q_2^{RAN} &= \frac{5\left(c^2+4b(a-4bh)\gamma\right)}{272b\gamma} > 0. \end{aligned} \tag{B.13}$$

(3) The impact of strategic inventory on first-period order quantities

Solving $Q_1^{AAI} - Q_1^{AAN} = -((-1+\theta_r\theta_m)(-c^2\ (-1+\theta_m)^2C_2 + 4b(bh(-2+\theta_m+\theta_r\theta_m)^2(9-2(5+4\theta_r)\theta_m + (2+6\theta_r+\theta_r^2)\theta_m^2) - a(-1+\theta_m)^2C_2)\gamma))/(8b\ (-1+\theta_m)^2 * (-34 + (41+61\theta_r)\theta_m - 2(8+25\theta_r+18\theta_r^2)\theta_m^2 + (2+10\theta_r+15\theta_r^2+7\theta_r^3)\theta_m^3)\gamma) = 0$ reveals the threshold of h, when $0 < h < h_{Q_1}^{AA} = ((-1+\theta_m)^2(9-2(4+5\theta_r)\theta_m + (2+4\theta_r+3\theta_r^2)\theta_m^2)(c^2+4ab\gamma))/(4b^2(-2+\theta_m+\theta_r\theta_m)^2(9-2(5+4\theta_r)\theta_m + (2+6\theta_r+\theta_r^2)\theta_m^2)\gamma)$, $Q_1^{AAI} > Q_1^{AAN}$.

Solving $Q_1^{ARI} - Q_1^{ARN} = -\left(c^2(-1+\theta_m)^2(9-8\theta_m+2\theta_m^2) + 4b\begin{pmatrix} -bh(-2+\theta_m)^2(9-10\theta_m+2\theta_m^2)+ \\ a(-1+\theta_m)^2(9-8\theta_m+2\theta_m^2)\end{pmatrix}\gamma\right)/(8b(-1+\theta_m)^2(-34+41\theta_m-16\theta_m^2+2\theta_m^3)\gamma) = 0$ reveals the threshold of h, when $0 < h < h_{Q_1}^{AR} = ((-1+\theta_m)^2(9-8\theta_m+2\theta_m^2)(c^2+4ab\gamma))/(4b^2(-2+\theta_m)^2(9-10\theta_m+2\theta_m^2)\gamma)$, $Q_1^{ARI} > Q_1^{ARN}$.

$$Q_1^{RAI} - Q_1^{RAN} = \frac{9\left(c^2+4b(a-4bh)\gamma\right)}{272b\gamma} > 0, \tag{B.14}$$

$$C_1 = \left(5-2(1+4\theta_r)\theta_m + \theta_r(2+3\theta_r)\theta_m^2\right);\ C_2 = \left(9-2(4+5\theta_r)\theta_m + \left(2+4\theta_r+3\theta_r^2\right)\theta_m^2\right). \tag{B.15}$$

□

Proof of Proposition 4.

To explore the effect of the strategic inventory, we compare the differences of decision-makers' profits when the retailer holds or does not hold strategic inventory under different altruistic scenarios (AA, AR, and RA).

$$\begin{aligned}
\Pi_r^{AAI} - \Pi_r^{AAN} = &\left(c^4(-1+\theta_m)^4C_3 + 4bc^2(-1+\theta_m)^2(-1+\theta_r\theta_m)\left(-bh(-2+\theta_m+\theta_r\theta_m)^2\right.\right.\\
&\cdot\left(-59+55\theta_m-18\theta_m^2+2\theta_m^3+\theta_r^4\theta_m^3(-41+21\theta_m)+\theta_r^3\theta_m^{2*}\right.\\
&\cdot\left(179-130\theta_m+31\theta_m^2\right)+\theta_r^2\theta_m\left(-261+218\theta_m-91\theta_m^2+14\theta_m^3\right)+\theta_r\left(127-66\theta_m+29\theta_m^2-12\theta_m^3+2\theta_m^4\right)\Big)\\
&+2a(-1+\theta_m)^2\left(-21+31\theta_m-14\theta_m^2+2^*\right.\\
&\cdot\theta_m^3+\theta_r^4\theta_m^3(-9+7\theta_m)+\theta_m^3\theta_m^2\left(51-58\theta_m+15\theta_m^2\right)+\theta_r^2\theta_m\left(-93+130\theta_m-59\theta_m^2+10\theta_m^3\right)\\
&+\theta_r\left(55-74\theta_m+37\theta_m^2-12\theta_m^3+2\theta_m^4\right)\Big)\Big)\gamma+8b^2(-2a^*\\
&\cdot bh(-1+\theta_m)^2(-2+\theta_m+\theta_r\theta_m)^2\left(59-55\theta_m+18\theta_m^2-2\theta_m^3+\theta_r^5\theta_m^4(-41+21\theta_m)+\theta_r^4\theta_m^3\left(220-151\theta_m+31\theta_m^2\right)\right.\\
&+\theta_r\left(-127+7\theta_m+26\theta_m^2-6\theta_m^3\right)+\\
&\cdot 2\theta_r^3\theta_m^2\left(-220+174\theta_m-61\theta_m^2+7\theta_m^3\right)+2\theta_r^2\theta_m\left(194-142\theta_m+60\theta_m^2-13\theta_m^3+\theta_m^4\right)\Big)+2a^2(-1+\theta_m)^4C_3\\
&+b^2h^2(-2+\theta_m+\theta_r\theta_m)^4(76-184\theta_m\\
&+181\theta_m^2-91\theta_m^3+22\theta_m^4-2\theta_m^5+\theta_r^5\theta_m^4(-9+7\theta_m)+\theta_r^4\theta_m^3\left(96-129\theta_m+43\theta_m^2\right)+\theta_r^3\theta_m^2\left(-289+471\theta_m-237\theta_m^2+35\theta_m^3\right)\\
&+\theta_r^2\theta_m(344-593\theta_m\\
&+327\theta_m^2-53\theta_m^3-5\theta_m^4\Big)+\theta_r\left(-144+180\theta_m+21\theta_m^2-123\theta_m^3+66\theta_m^4-10\theta_m^5\right)\Big)\Big)\gamma^2\Big)/\Big(32b^3(-1+\theta_r)(-1+\theta_m)^3\\
&\cdot(-34+(41+61\theta_r)\theta_m-2(8+25\theta_r\\
&+18\theta_r^2)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\Big)^2\gamma^2\Big)=0.
\end{aligned} \tag{B.16}$$

(1) For retailer's profits:
Solving

$$h_{\Pi_r}^{AA} = \begin{cases} h_{\Pi_r 1}^{AA}, 0<\theta_m<\dfrac{5\sqrt{2}-1}{7}, 0<\theta_r<f_1(\theta_m), \\ h_{\Pi_r 1}^{AA}, \dfrac{5\sqrt{2}-1}{7}<\theta_m<1, 0<\theta_r<f_2(\theta_m,\theta_r), \\ h_{\Pi_r 2}^{AA}, \dfrac{5\sqrt{2}-1}{7}<\theta_m<1, f_2(\theta_m,\theta_r)<\theta_r<f_1(\theta_m), \end{cases} \tag{B.17}$$

$$\begin{aligned} f_1(\theta_m) \rightarrow & \frac{51-58\theta_m+15\theta_m^2}{36\theta_m-28\theta_m^2} - \frac{1}{4\sqrt{3}}\left(\sqrt{\left(\frac{1}{\theta_m^3}\left(\frac{3\theta_m\left(51-58\theta_m+15\theta_m^2\right)^2}{(9-7\theta_m)^2} - \frac{8\theta_m\left(-93+130\theta_m-59\theta_m^2+10\theta_m^3\right)}{-9+7\theta_m} + \frac{4*2^{2/3}(-1+\theta_m)^4\theta_m^2\left(117-42\theta_m+5\theta_m^2\right)}{(-9+7\theta_m)C_4} + \frac{4*2^{1/3}C_4}{-9+7\theta_m}\right)\right)}\right) \\ & - \frac{1}{2\sqrt{6}}\left(\sqrt{\left(\frac{1}{\theta_m^3}\left(\frac{3\theta_m\left(51-58\theta_m+15\theta_m^2\right)^2}{(9-7\theta_m)^2} + \frac{8\theta_m\left(93-130\theta_m+59\theta_m^2-10\theta_m^3\right)}{-9+7\theta_m} - \frac{2*2^{2/3}(-1+\theta_m)^4\theta_m^2\left(117-42\theta_m+5\theta_m^2\right)}{(-9+7\theta_m)C_4} + \frac{2*2^{1/3}C_4}{9-7\theta_m} - \frac{3\sqrt{3}(-1+\theta_m)^3\left(-2457+2331\theta_m-427\theta_m^2+41\theta_m^3\right)}{(-9+7\theta_m)^3\sqrt{\left(\left(1/\theta_m^3\right)\left(\left(3\theta_m\left(51-58\theta_m+15\theta_m^2\right)^2/(9-7\theta_m)^2\right)-\left(8\theta_m\left(-93+130\theta_m-59\theta_m^2+10\theta_m^3\right)/(-9+7\theta_m)\right)+\left(\left(4*2^{2/3}(-1+\theta_m)^4\theta_m^2\left(117-42\theta_m+5\theta_m^2\right)\right)/(-9+7\theta_m)C_4\right)+\left(\left(4*2^{1/3}C_4\right)/(-9+7\theta_m)\right)\right)\right)}}\right)\right)}\right), \end{aligned} \tag{B.18}$$

$$f_2(\theta_m,\theta_r) \rightarrow \left(\begin{array}{c} 76-184\theta_m+181\theta_m^2-91\theta_m^3+22\theta_m^4-2\theta_m^5+\left(-144+180\theta_m+21\theta_m^2-123\theta_m^3+66\theta_m^4-10\theta_m^5\right)\theta_r+\left(344\theta_m-593\theta_m^2+327\theta_m^3-53*\theta_m^4-5\theta_m^5\right)\theta_r^2+ \\ \left(-289\theta_m^2+471\theta_m^3-237\theta_m^4+35\theta_m^5\right)\theta_r^3+\left(96\theta_m^3-129\theta_m^4+43\theta_m^5\right)\theta_r^4+\left(-9\theta_m^4+7\theta_m^5\right)\theta_r^5 \end{array}\right)=0. \tag{B.19}$$

reveals the threshold of h, when $0<h<h_{\Pi_r}^{AA}$, $\Pi_r^{AAI}>\Pi_r^{AAN}$.

Solving

$$\Pi_r^{ARI}-\Pi_r^{ARN} = \frac{c^4(-1+\theta_m)^4\left(-21+31\theta_m-14\theta_m^2+2\theta_m^3\right)+4bc^2(-1+\theta_m)^2\left(-bh(-2+\theta_m)^2\left(-59+55\theta_m-18\theta_m^2+2\theta_m^3\right)+2a(-1+\theta_m)^2\left(-21+31*\theta_m-14\theta_m^2+2\theta_m^3\right)\right)\gamma+8b^2\left(-2abh\left(2-3\theta_m+\theta_m^2\right)^2\left(-59+55\theta_m-18\theta_m^2+2\theta_m^3\right)+2a^2(-1+\theta_m)^4\left(-21+31\theta_m-14\theta_m^2+2\theta_m^3\right)+b^2h^2*(-2+\theta_m)^4\left(-76+184\theta_m-181\theta_m^2+91\theta_m^3-22\theta_m^4+2\theta_m^5\right)\right)\gamma^2}{32b^3(-1+\theta_m)^3\left(34-41\theta_m+16\theta_m^2-2\theta_m^3\right)^2\gamma^2}=0, \tag{B.20}$$

reveals threshold of h, when $0<h<h_{\Pi_r}^{AR}$, $\Pi_r^{ARI}>\Pi_r^{ARN}$.

$$h_{\Pi_r}^{AR} = \frac{c^2(-1+\theta_m)^2\left(-59+55\theta_m-18\theta_m^2+2\theta_m^3\right)+b\gamma\left(4a(-1+\theta_m)^2\left(-59+55\theta_m-18\theta_m^2+2\theta_m^3\right)-b(-2+\theta_m)^2*(-C_5)\sqrt{-\left(\left(\left((-1+\theta_m)^4\left(17-12\theta_m+2\theta_m^2\right)^2\left(-1-22\theta_m+25\theta_m^2-12\theta_m^3+2\theta_m^4\right)\left(c^2+4ab\gamma\right)^2\right)/\left(b^4(-2+\theta_m)^4C_5^2\gamma^2\right)\right)\right)}\right)}{-4b^2(-2+\theta_m)^2C_5\gamma}. \tag{B.21}$$

Solving $\Pi_r^{RAI}-\Pi_r^{RAN}=(c^2+4b(a-4bh)\gamma)\ (c^2(-21+55\theta_r)+4b\ (8bh(19-36\theta_r)+a(-21+55\theta_r))\gamma)/36992b^3(-1+\theta_r)\gamma^2=0$ reveals the threshold of h, when $0<\theta_r<21/55$, $0<h<h_{\Pi}^{RA}=(-21+55\theta_r)\ (c^2+4ab\gamma)/32b^2(-19+36\theta_r)\gamma$, $\Pi_r^{RAI}>\Pi_r^{RAN}$.

(2) For manufacturer's profits, solving

$$\Pi_m^{AAI}-\Pi_m^{AAN} = \frac{(-1+\theta_r\theta_m)\left(\begin{array}{c} c^4(-1+\theta_m)^4C_6+8bc^2(-1+\theta_m)^2\left(\begin{array}{c} a(-1+\theta_m)^2C_6-bh(-2+\theta_m+\theta_r\theta_m)^2* \\ \left(\begin{array}{c} -17+4(12+5\theta_r)\theta_m+\left(-35-74\theta_r+7\theta_r^2\right)\theta_m^2+ \\ \left(10+40\theta_r+34\theta_r^2-16\theta_r^3\right)\theta_m^3+ \\ \left(-1-6\theta_r-11\theta_r^2-4\theta_r^3+5\theta_r^4\right)\theta_m^4 \end{array}\right) \end{array}\right)\gamma+ \\ 8b^2\left(\begin{array}{c} 2a^2C_6(-1+\theta_m)^4+b^2h^2(-2+\theta_m+\theta_r\theta_m)^4\left(\begin{array}{c} -34+8(12+5\theta_r)\theta_m-2\left(43+58\theta_r+\theta_r^2\right)* \\ \theta_m^2+\left(28+88\theta_r+28\theta_r^2-8\theta_r^3\right)\theta_m^3+ \\ \left(-3-16\theta_r-20\theta_r^2+4\theta_r^3+\theta_r^4\right)\theta_m^4 \end{array}\right)- \\ 4abh(-1+\theta_m)^2(-2+\theta_m+\theta_r\theta_m)^2\left(\begin{array}{c} -17+4(12+5\theta_r)\theta_m+\left(-35-74\theta_r+7\theta_r^2\right)\theta_m^2+ \\ \left(10+40\theta_r+34\theta_r^2-16\theta_r^3\right)\theta_m^3+ \\ \left(-1-6\theta_r-11\theta_r^2-4\theta_r^3+5\theta_r^4\right)\theta_m^4 \end{array}\right) \end{array}\right)\gamma^2 \end{array}\right)}{\left(16b^3(-1+\theta_r)(-1+\theta_m)^3\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^2\gamma^2\right)}=0, \tag{B.22}$$

reveals the threshold of h, when $h^{AA}_{\Pi_m} < h < {}^{AA}_{h}$, $\Pi^{AAI}_m > \Pi^{AAN}_m$.

$$h^{AA}_{\Pi_m} = \begin{cases} 0, 0 < \theta_m \leq 2 - \sqrt{1 + \dfrac{1}{\sqrt{2}}}, 0 < \theta_r < 1 \\ h^{AA}_{\Pi_m 2}, 2 - \sqrt{1 + \dfrac{1}{\sqrt{2}}} < \theta_m < 0.705, 0 < \theta_r < f_3(\theta_m) \\ 0, 2 - \sqrt{1 + \dfrac{1}{\sqrt{2}}} < \theta_m < 0.705, f_3(\theta_m) < \theta_r < 1 \\ h^{AA}_{\Pi_m 1}, 0.705 \leq \theta_m < 1, 0 < \theta_r < f_4(\theta_m) \\ h^{AA}_{\Pi_m 2}, 0.705 \leq \theta_m < 1, f_4(\theta_m) < \theta_r < f_3(\theta_m) \\ 0, 0.705 \leq \theta_m < 1, f_3(\theta_m) < \theta_r < 1 \end{cases}, \tag{B.23}$$

$$f_3(\theta_m) = \frac{-1 + \sqrt{2}\sqrt{(-1+\theta_m)^2} + \sqrt{\left(2 + \sqrt{(-1+\theta_m)^2} - 2\theta_m\right)(-1+\theta_m)/\theta_m}}{\theta_m}. \tag{B.24}$$

$$\begin{aligned} f_4(\theta_m) = {} & -1 + \frac{2}{\theta_m} - \frac{1}{\sqrt{6}}\left(\sqrt{\frac{\left(-556\theta_m{}^5 + 834\theta_m{}^6 - 556\theta_m{}^7 + 139\theta_m{}^8 + 26\theta_m{}^2 C_7{}^{1/3} - 52\theta_m{}^3 C_7{}^{1/3} + C_7{}^{2/3} + \theta_m{}^4\left(139 + 26C_7{}^{1/3}\right)\right)}{\left(\theta_m{}^4 C_7{}^{1/3}\right)}}\right) - \\ & \frac{1}{2\sqrt{3}}\left(\sqrt{\left(\begin{array}{c} 80 + 8/\theta_m{}^2 + 24(-2+\theta_m)^2/\theta_m{}^2 - 112/\theta_m - \left(278(-1+\theta_m)^4\right)/C_7{}^{1/3} - \dfrac{1}{\theta_m{}^4} 2C_7{}^{1/3} + \\ \left(\dfrac{96\sqrt{6}\,(-1+\theta_m)^3}{\left(\theta_m{}^3\sqrt{\left(\left(-556\theta_m{}^5 + 834\theta_m{}^6 - 556\theta_m{}^7 + 139\theta_m{}^8 + 26\theta_m{}^2 C_7{}^{1/3} - 52\theta_m{}^3 C_7{}^{1/3} + C_7{}^{2/3} + \theta_m{}^4\left(139 + 26C_7{}^{1/3}\right)\right)\right)/\left(\theta_m{}^4 C_7{}^{1/3}\right)}\right)}\right) \end{array}\right)}\right), \\ & \sqrt{2}\,\frac{\sqrt{\left((-1+\theta_r)^2 * (-1+\theta_m)^4\theta_m^2\left(-2 + 4\theta_m + \left(-1 - 2\theta_r + \theta_r^2\right)\theta_m^2\right)\left(17 - 2(6 + 11\theta_r)\theta_m + \left(2 + 8\theta_r + 7\theta_r^2\right)\theta_m^2\right)^2\left(c^2 + 4ab\gamma\right)^2\right)}}{\left(b^4(-2 + \theta_m + \theta_r\theta_m)^4(-34 + 8(12 + 5\theta_r)\theta_m - 2 * \left(43 + 58\theta_r + \theta_r^2\right)\theta_m^2 + \left(28 + 88\theta_r + 28\theta_r^2 - 8\theta_r^3\right)\theta_m^3 + \left(-3 - 16\theta_r - 20\theta_r^2 + 4\theta_r^3 + \theta_r^4\right)\theta_m^4)^2\gamma^2\right)}, \end{aligned} \tag{B.25}$$

$$\begin{aligned} h^{AA}_{\Pi_m 1} = {} & \frac{1}{4}\,\frac{2(-1+\theta_m)^2\left(-17 + 4(12 + 5\theta_r)\theta_m + \left(-35 - 74\theta_r + 7\theta_r^2\right)\theta_m^2 + \left(10 + 40\theta_r + 34\theta_r^2 - 16\theta_r^3\right)\theta_m^3 + \left(-1 - 6\theta_r - 11\theta_r^2 - 4\theta_r^3 + 5\theta_r^4\right)\theta_m^4\right)\left(c^2 + 4ab\gamma\right))}{(b^2 * (-2 + \theta_m + \theta_r\theta_m)^2(-34 + 8(12 + 5\theta_r)\theta_m - 2\left(43 + 58\theta_r + \theta_r^2\right)\theta_m^2 + \left(28 + 88\theta_r + 28\theta_r^2 - 8\theta_r^3\right)\theta_m^3 + \left(-3 - 16\theta_r - 20\theta_r^2 + 4\theta_r^3 + \theta_r^4\right)\theta_m^4)\gamma)} - \\ & \sqrt{2}\,\frac{\sqrt{\left((-1+\theta_r)^2 * (-1+\theta_m)^4\theta_m^2\left(-2 + 4\theta_m + \left(-1 - 2\theta_r + \theta_r^2\right)\theta_m^2\right)\left(17 - 2(6 + 11\theta_r)\theta_m + \left(2 + 8\theta_r + 7\theta_r^2\right)\theta_m^2\right)^2\left(c^2 + 4ab\gamma\right)^2\right)}}{\left(b^4(-2 + \theta_m + \theta_r\theta_m)^4(-34 + 8(12 + 5\theta_r)\theta_m - 2 * \left(43 + 58\theta_r + \theta_r^2\right)\theta_m^2 + \left(28 + 88\theta_r + 28\theta_r^2 - 8\theta_r^3\right)\theta_m^3 + \left(-3 - 16\theta_r - 20\theta_r^2 + 4\theta_r^3 + \theta_r^4\right)\theta_m^4)^2\gamma^2\right)}, \end{aligned} \tag{B.26}$$

$$\begin{aligned} h^{AA}_{\Pi_m 2} = {} & \frac{1}{4}\,\frac{\left(2(-1+\theta_m)^2\left(-17 + 4(12 + 5\theta_r)\theta_m + \left(-35 - 74\theta_r + 7\theta_r^2\right)\theta_m^2 + \left(10 + 40\theta_r + 34\theta_r^2 - 16\theta_r^3\right)\theta_m^3 + \left(-1 - 6\theta_r - 11\theta_r^2 - 4\theta_r^3 + 5\theta_r^4\right)\theta_m^4\right)\left(c^2 + 4ab\gamma\right)\right)}{b^2 * (-2 + \theta_m + \theta_r\theta_m)^2\left(-34 + 8(12 + 5\theta_r)\theta_m - 2\left(43 + 58\theta_r + \theta_r^2\right)\theta_m^2 + \left(28 + 88\theta_r + 28\theta_r^2 - 8\theta_r^3\right)\theta_m^3 + \left(-3 - 16\theta_r - 20\theta_r^2 + 4\theta_r^3 + \theta_r^4\right)\theta_m^4\right)\gamma)} \\ & + \frac{\sqrt{2}\sqrt{\left((-1+\theta_r)^2 * (-1+\theta_m)^4\theta_m^2\left(-2 + 4\theta_m + \left(-1 - 2\theta_r + \theta_r^2\right)\theta_m^2\right)\left(17 - 2(6 + 11\theta_r)\theta_m + \left(2 + 8\theta_r + 7\theta_r^2\right)\theta_m^2\right)^2\left(c^2 + 4ab\gamma\right)^2\right)}}{\left(b^4(-2 + \theta_m + \theta_r\theta_m)^4(-34 + 8(12 + 5\theta_r)\theta_m - 2 * \left(43 + 58\theta_r + \theta_r^2\right)\theta_m^2 + \left(28 + 88\theta_r + 28\theta_r^2 - 8\theta_r^3\right)\theta_m^3 + \left(-3 - 16\theta_r - 20\theta_r^2 + 4\theta_r^3 + \theta_r^4\right)\theta_m^4)^2\gamma^2\right)}. \end{aligned} \tag{B.27}$$

Solving

$$\Pi_m^{ARI} - \Pi_m^{ARN} = -\frac{\left(\begin{array}{c} c^4(-1+\theta_m)^4\left(17-48\theta_m+44\theta_m^2-16\theta_m^3+2\theta_m^4\right)+ \\ 8bc^2(-1+\theta_m)^2 * \\ \left(-bh(-2+\theta_m)^2\left(17-48\theta_m+35\theta_m^2-10\theta_m^3+\theta_m^4\right)+a(-1+\theta_m)^2\left(17-48\theta_m+44\theta_m^2-16\theta_m^3+2\theta_m^4\right)\right)\gamma+ \\ 8b^2\left(\begin{array}{c} -4abh\left(2-3\theta_m+\theta_m^2\right)^2\left(17-48\theta_m+35\theta_m^2-10\theta_m^3+\theta_m^4\right)+ \\ 2a^2(-1+\theta_m)^4\left(17-48\theta_m+44\theta_m^2-16\theta_m^3+2\theta_m^4\right)+b^2h^2(-2+\theta_m)^4\left(34-96\theta_m+86\theta_m^2-28\theta_m^3+3\theta_m^4\right) \end{array}\right)\gamma^2 \end{array}\right)}{\left(16b^3(-1+\theta_m)^3\left(34-41\theta_m+16\theta_m^2-2\theta_m^3\right)^2\gamma^2\right)} = 0, \tag{B.28}$$

reveals the threshold of h, when $h_{\Pi_m}^{AR} < h < h^{AR}$, $\Pi_m^{ARI} > \Pi_m^{ARN}$.

$$h_{\Pi_m}^{AR} = \begin{cases} 0, 0 < \theta_m < 2 - \sqrt{1 + \frac{1}{\sqrt{2}}} \\ h_{\Pi_m 1}^{AR}, 2 - \sqrt{1 + \frac{1}{\sqrt{2}}} < \theta_m < 0.705 \\ h_{\Pi_m 2}^{AR}, 0.705 < \theta_m < 1 \end{cases}, \tag{B.29}$$

$$h_{\Pi_m 1}^{AR} = \frac{\left(2c^2(-1+\theta_m)^2\left(17-48\theta_m+35\theta_m^2-10\theta_m^3+\theta_m^4\right)+b\gamma\left(8a(-1+\theta_m)^2\left(17-48\theta_m+35\theta_m^2-10\theta_m^3+\theta_m^4\right)+\sqrt{2}\,b(-2+\theta_m)^2\left(34-96\theta_m+86\theta_m^2-28\theta_m^3+3\theta_m^4\right)*\sqrt{\left(-\left(\left((-1+\theta_m)^4\theta_m^2\left(2-4\theta_m+\theta_m^2\right)*\left(17-12\theta_m+2\theta_m^2\right)^2\left(c^2+4ab\gamma\right)^2\right)/\left(b^4(-2+\theta_m)^4\left(34-96\theta_m+86\theta_m^2-28\theta_m^3+3\theta_m^4\right)^2\gamma^2\right)\right)\right)}\right)\right)}{4b^2(-2+\theta_m)^2\left(34-96o2+86\theta_m^2-28\theta_m^3+3\theta_m^4\right)\gamma}, \tag{B.30}$$

$$h_{\Pi_m 2}^{AR} = \frac{\left(\begin{array}{c} 2c^2(-1+\theta_m)^2\left(17-48\theta_m+35\theta_m^{\ 2}-10\theta_m^{\ 3}+\theta_m^{\ 4}\right)+ \\ b\gamma\left(\begin{array}{c} 8a(-1+\theta_m)^2\left(17-48\theta_m+35\theta_m^{\ 2}-10\theta_m^{\ 3}+\theta_m^{\ 4}\right)-\sqrt{2}\,b(-2+\theta_m)^2\left(34-96\theta_m+86\theta_m^{\ 2}-28\theta_m^{\ 3}+3\theta_m^{\ 4}\right)* \\ \sqrt{\left(-\left(\begin{array}{c}(-1+\theta_m)^4\theta_m^{\ 2}\left(2-4\theta_m+\theta_m^{\ 2}\right)* \\ \left(17-12\theta_m+2\theta_m^{\ 2}\right)^2\left(c^2+4ab\gamma\right)^2\end{array}\right)/\left(b^4(-2+\theta_m)^4\left(34-96\theta_m+86\theta_m^{\ 2}-28\theta_m^{\ 3}+3\theta_m^{\ 4}\right)^2\gamma^2\right)\right)} \end{array}\right) \end{array}\right)}{\left(4b^2(-2+\theta_m)^2\left(34-96\theta_m+86\theta_m^{\ 2}-28\theta_m^{\ 3}+3\theta_m^{\ 4}\right)\gamma\right)},$$

$$\prod_m^{RAI} - \prod_m^{RAN} = -\frac{\left(c^2+4b(a-4bh)\gamma\right)^2}{1088b^3(-1+\theta_r)\gamma^2} > 0. \tag{B.32}$$

(B.31)

(3) For profits of the supply chain, solving

$$\Pi^{AAI}-\Pi^{AAN}=\frac{\left(\begin{array}{c} c^4(-1+\theta_m)^4\left(\begin{array}{c}55-4(18+37\theta_r)\theta_m+6\left(5+26\theta_r+24\theta_r^2\right)\theta_m^2-\\ 4\left(1+12\theta_r+27\theta_r^2+15\theta_r^3\right)\theta_m^3+\theta_r\left(4+18\theta_r+24\theta_r^2+9\theta_r^3\right)\theta_m^4\end{array}\right)+\\ 4bc^2(-1+\theta_m)^2(-1+\theta_r\theta_m)*\\ \left(\begin{array}{c}2a(-1+\theta_m)^2\left(-55+(72+93\theta_r)\theta_m-3\left(10+28\theta_r+17\theta_r^2\right)\theta_m^2+\left(4+18\theta_r+24\theta_r^2+9\theta_r^3\right)\theta_m^3\right)-\\ bh(-2+\theta_m+\theta_r\theta_m)^2\left(-127+3(40+87\theta_r)\theta_m-\left(38+164\theta_r+179\theta_r^2\right)\theta_m^2+\left(4+26\theta_r+56\theta_r^2+41\theta_r^3\right)\theta_m^3\right)\end{array}\right)\gamma+\\ 8b^2\left(\begin{array}{c} b^2h^2(-2+\theta_m+\theta_r\theta_m)^4(-4+\theta_m+3\theta_r\theta_m)^2\left(9-2(5+4\theta_r)\theta_m+\left(2+6\theta_r+\theta_r^2\right)\theta_m^2\right)+\\ 2a^2(-1+\theta_m)^4\left(\begin{array}{c}55-4(18+37\theta_r)\theta_m+6\left(5+26\theta_r+24\theta_r^2\right)\theta_m^2-4\left(1+12\theta_r+27\theta_r^2+15\theta_r^3\right)\theta_m^3+\\ \theta_r\left(4+18\theta_r+24\theta_r^2+9\theta_r^3\right)\theta_m^4\end{array}\right)-\\ 2abh(-1+\theta_m)^2(-2+\theta_m+\theta_r\theta_m)^2*\\ \left(\begin{array}{c}127-4(30+97\theta_r)\theta_m+\left(38+284\theta_r+440\theta_r^2\right)\theta_m^2-4\left(1+16\theta_r+55\theta_r^2+55\theta_r^3\right)\theta_r^3+\\ \theta_r\left(4+26\theta_r+56\theta_r^2+41\theta_r^3\right)\theta_m^4\end{array}\right)\end{array}\right)\gamma^2\end{array}\right)}{\left(32b^3(-1+\theta_m)^2\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^2\gamma^2\right)}=0, \tag{B.33}$$

reveals the threshold of h, when $0<h<h_{\Pi}^{AA}$, $\Pi^{AAI}>\Pi^{AAN}$.

$$h_{\Pi}^{AA}=\frac{\left(\begin{array}{c} c^2(-1+\theta_m)^2\left(\begin{array}{c}127-4(30+97\theta_r)\theta_m+\left(38+284\theta_r+440\theta_r^2\right)\theta_m^2-\\ 4\left(1+16\theta_r+55\theta_r^2+55\theta_r^3\right)\theta_m^3+\theta_r\left(4+26\theta_r+56\theta_r^2+41\theta_r^3\right)\theta_m^4\end{array}\right)-\\ b\gamma\left(\begin{array}{c} -4a(-1+\theta_m)^2\left(\begin{array}{c}127-4(30+97\theta_r)\theta_m+\left(38+284\theta_r+440\theta_r^2\right)\theta_m^2-\\ 4\left(1+16\theta_r+55\theta_r^2+55\theta_r^3\right)\theta_m^3+\theta_r\left(4+26\theta_r+56\theta_r^2+41\theta_r^3\right)\theta_m^4\end{array}\right)+\\ b\left(9-2(5+4\theta_r)\theta_m+\left(2+6\theta_r+\theta_r^2\right)\theta_m^2\right)*\\ \left(8-2(3+5\theta_r)\theta_m+\left(1+4\theta_r+3\theta_r^2\right)\theta_m^2\right)^2*\\ \sqrt{\left(\left(\begin{array}{c}(-1+\theta_m)^4\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_{m,}^2\right)^2*\\ \left(\begin{array}{c}1+(56-60\theta_r)\theta_m+6\left(-5-18\theta_r+24\theta_r^2\right)\theta_m^2+\\ \left(4+48\theta_r+60\theta_r^2-116\theta_r^3\right)\theta_m^3+\theta_r\left(-4-18\theta_r-8\theta_r^2+31\theta_r^3\right)\theta_m^4\end{array}\right)\left(c^2+4ab\gamma\right)^2\end{array}\right)\Big/\left(\begin{array}{c}b^4\left(\begin{array}{c}9-2(5+4\theta_r)\theta_m+\\ \left(2+6\theta_r+\theta_r^2\right)\theta_m^2\end{array}\right)^2*\\ \left(\begin{array}{c}8-2(3+5\theta_r)\theta_m+\\ \left(1+4\theta_r+3\theta_r^2\right)\theta_m^2\end{array}\right)^4\gamma^2\end{array}\right)\right)}\end{array}\right)\end{array}\right)}{\left(4b^2(-2+\theta_m+\theta_r\theta_m)^2(-4+\theta_m+3\theta_r\theta_m)^2\left(9-2(5+4\theta_r)\theta_m+\left(2+6\theta_r+\theta_r^2\right)\theta_m^2\right)\gamma\right)}. \tag{B.34}$$

Solving

$$\Pi^{ARI} - \Pi^{ARN} = -\frac{\begin{pmatrix} c^4(-1+\theta_m)^4\left(-55+72\theta_m-30\theta_m^2+4\theta_m^3\right)+4bc^2(-1+\theta_m)^2\begin{pmatrix} -bh(-2+\theta_m)^2\left(-127+120\theta_m-38\theta_m^2+4\theta_m^3\right)+ \\ 2a(-1+\theta_m)^2\left(-55+72\theta_m-30\theta_m^2+4\theta_m^3\right)\end{pmatrix}\gamma+ \\ 8b^2\begin{pmatrix} -b^2h^2(-4+\theta_m)^2(-2+\theta_m)^4\left(9-10\theta_m+2\theta_m^2\right)-2abh\left(2-3\theta_m+\theta_m^2\right)^2\left(-127+120\theta_m-38\theta_m^2+4\theta_m^3\right)+ \\ 2a^2(-1+\theta_m)^4\left(-55+72\theta_m-30\theta_m^2+4\theta_m^3\right)\end{pmatrix}\gamma^2 \end{pmatrix}}{\left(32b^3\left(34-75\theta_m+57\theta_m^2-18\theta_m^3+2\theta_m^4\right)^2\gamma^2\right)} = 0, \tag{B.35}$$

reveals the threshold of h, when $0 < h < h_{\Pi}^{AR}$, $\Pi^{ARI} > \Pi^{ARN}$.

$$h_{\Pi}^{AR} = \frac{\left(\begin{array}{c} -c^2(-1+\theta_m)^2\left(-127+120\theta_m-38\theta_m^2+4\theta_m^3\right)+b\gamma * \\ \left(\begin{array}{c} -4a(-1+\theta_m)^2\left(-127+120\theta_m-38\theta_m^2+4\theta_m^3\right)- \\ b\left(8-6\theta_m+\theta_m^2\right)^2\left(9-10\theta_m+2\theta_m^2\right)\sqrt{\left((-1+\theta_m)^4\left(17-12\theta_m+2\theta_m^2\right)^2\left(1+56\theta_m-30\theta_m^2+4\theta_m^3\right)\left(c^2+4ab\gamma\right)^2/\left(b^4\left(8-6\theta_m+\theta_m^2\right)^4\left(9-10\theta_m+2\theta_m^2\right)^2\gamma^2\right)\right)} \end{array}\right) \end{array}\right)}{\left(4b^2(-4+\theta_m)^2(-2+\theta_m)^2\left(9-10\theta_m+2\theta_m^2\right)\gamma\right)}. \tag{B.36}$$

Solving $\Pi^{RAI} - \Pi^{RAN} = (55c^4 + 8bc^2(55a - 254bh)\gamma + 16b^2(55a^2 - 508abh + 1152b^2h^2)\gamma^2)/(36992b^3\gamma^2) = 0$ reveals the threshold of h, when $0 < h < h_{\Pi}^{RA} = 55(c^2 + 4ab\gamma)/(1152b^2\gamma)$, $\Pi^{RAI} > \Pi^{RAN}$.

$$C_3 = \left(\begin{array}{c} 21-31\theta_m+14\theta_m^2-2\theta_m^3+\theta_r^5\theta_m^4(-9+7\theta_m) \\ +5\theta_r^4\theta_m^3\left(12-13\theta_m+3\theta_m^2\right)-\theta_r\left(55-53\theta_m+6\theta_m^2+2\theta_m^3\right)+2\theta_r^3\theta_m^2\left(-72+94\theta_m-37\theta_m^2+5\theta_m^3\right)+2\theta_r^2\theta_m\left(74-102\theta_m+48\theta_m^2-11\theta_m^3+\theta_m^4\right)\end{array}\right), \tag{B.37}$$

$$C_4 = \left(\begin{array}{c} 999\theta_m^3-5994\theta_m^4+14868\theta_m^5-19264\theta_m^6+13146\theta_m^7-3444\theta_m^8-1036\theta_m^9+912\theta_m^{10}-201\theta_m^{11}+14\theta_m^{12}+ \\ 3\sqrt{3}\sqrt{-(-1+\theta_m)^{12}\theta_m^6\left(81675-127764\theta_m+69732\theta_m^2-17444\theta_m^3+2103\theta_m^4-112\theta_m^5+2\theta_m^6\right)}\end{array}\right)^{(1/3)}, \tag{B.38}$$

$$C_5 = \left(76-184\theta_m+181\theta_m^2-91\theta_m^3+22\theta_m^4-2\theta_m^5\right), \tag{B.39}$$

$$C_6 = \left(-17+4(12+5\theta_r)\theta_m-2\left(22+28\theta_r+{\theta_r}^2\right){\theta_m}^2-4\left(-4-10\theta_r-4{\theta_r}^2+{\theta_r}^3\right){\theta_m}^3+\left(-2-8\theta_r-8{\theta_r}^2+{\theta_r}^4\right){\theta_m}^4\right), \tag{B.40}$$

$$C_7 = \left(-1639\theta_m^6+9834\theta_m^7-24585\theta_m^8+32780\theta_m^9-24585\theta_m^{10}+9834\theta_m^{11}-1639\theta_m^{12}+3\sqrt{78}\sqrt{(-1+\theta_m)^{12}\theta_m^{12}}\right), \tag{B.41}$$

$$C_8 = \left(-119\theta_m^6+714\theta_m^7-1785\theta_m^8+2380\theta_m^9-1785\theta_m^{10}+714\theta_m^{11}-119\theta_m^{12}+3\sqrt{1545}\sqrt{(-1+\theta_m)^{12}\theta_m^{12}}\right). \tag{B.42}$$

□

Proof of Corollary 1. To explore the impact of altruistic preferences on the range of strategic inventory that the retailer can hold, we compare thresholds under different altruistic scenarios (AAI, ARI, and RAI).

(1) In scenario ARI, $\partial h^{AR}/\partial\theta_m = (20 - 25\theta_m - 14\theta_m^2 + 31\theta_m^3 - 14\theta_m^4 + 2\theta_m^5)(c^2 + 4ab\gamma)/4b^2(-2+\theta_m)^3(5 - 5\theta_m + \theta_m^2)^2\gamma < 0.$.

(2) In scenario RAI, $\partial h^{RA}/\partial\theta_r = 0$.

(3) In scenario AAI,

$$\frac{\partial h^{AA}}{\partial\theta_m} = \frac{(-1+\theta_r)(-1+\theta_m)\left(20 - 5(1+15\theta_r)\theta_m + \left(-19+53\theta_r+86\theta_r^2\right)\theta_m^2 + \left(12+2\theta_r-55\theta_r^2-39\theta_r^3\right)\theta_m^3 + \left(-2-4\theta_r+5\theta_r^2+15\theta_r^3+6\theta_r^4\right)\theta_m^4\right)\left(c^2+4ab\gamma\right)}{4b^2\left(-2+\theta_m+\theta_r\theta_m\right)^3\left(5-5(1+\theta_r)\theta_m+\left(1+3\theta_r+\theta_r^2\right)\theta_m^2\right)^2\gamma} < 0, \tag{B.43}$$

$$\frac{\partial h^{AA}}{\partial\theta_r} = -\frac{(-1+\theta_m)^2\theta_m\left(20 - 5(1+15\theta_r)\theta_m + \left(-19+53\theta_r+86\theta_r^2\right)\theta_m^2 + \left(12+2\theta_r-55\theta_r^2-39\theta_r^3\right)\theta_m^3 + \left(-2-4\theta_r+5\theta_r^2+15\theta_r^3+6\theta_r^4\right)\theta_m^4\right)\left(c^2+4ab\gamma\right)}{4b^2\left(-2+\theta_m+\theta_r\theta_m\right)^3\left(5-5(1+\theta_r)\theta_m+\left(1+3\theta_r+\theta_r^2\right)\theta_m^2\right)^2\gamma} > 0. \tag{B.44}$$

□

Proof of Proposition 5.

To explore the effect of the retailer's altruistic preference on decisions, we compare four different scenarios (RAI, AAI, RAN, and AAN).

(1) In scenario RAI,

$$\begin{aligned}
\frac{\partial w_1^{RAI}}{\partial\theta_r} &= \frac{9c^2 + 4b(9a - 2bh)\gamma}{68b^2(-1+\theta_r)^2\gamma} > 0,\\
\frac{\partial w_2^{RAI}}{\partial\theta_r} &= \frac{3c^2 + 4b(3a + 5bh)\gamma}{34b^2(-1+\theta_r)^2\gamma} > 0,\\
\frac{\partial e^{RAI}}{\partial\theta_r} &= \frac{\partial Q_1^{RAI}}{\partial\theta_r} = \frac{\partial Q_2^{RAI}}{\partial\theta_r} = \frac{\partial q_1^{RAI}}{\partial\theta_r} = \frac{\partial p_1^{RAI}}{\partial\theta_r} = \frac{\partial I^{RAI}}{\partial\theta_r} = \frac{\partial q_2^{RAI}}{\partial\theta_r} = \frac{\partial p_2^{RAI}}{\partial\theta_r} = 0.
\end{aligned} \tag{B.45}$$

(2) In scenario AAI,

$$\frac{\partial e^{AAI}}{\partial\theta_r} = 0, \tag{B.46}$$

$$\frac{\partial w_1^{AAI}}{\partial\theta_r} = \frac{\left((-1+\theta_r\theta_m)\left(c^2(-1+\theta_m)\left(153-36(6+11\theta_r)\theta_m+2\left(59+206\theta_r+194\theta_r{}^2\right)\theta_m^2-2\left(15+73\theta_r+133\theta_r^2+85\theta_r^3\right)\theta_m^3+\left(3+18\theta_r+46\theta_r^2+58\theta_r^3+28\theta_r^4\right)\theta_m^4\right)-2b\left(bh(-2+\theta_m+\theta_r\theta_m)^2\left(-17+3(8+9\theta_r)\theta_m-3\left(3+10\theta_r+4\theta_r^2\right)\theta_m^2+\left(1+6\theta_r+9\theta_r^2+\theta_r^3\right)\theta_m^3\right)-2a(-1+\theta_m)\left(153-36(6+11\theta_r)\theta_m+2\left(59+206\theta_r+194\theta_r^2\right)\theta_m^2-2\left(15+73\theta_r+133\theta_r^2+85\theta_r^3\right)\theta_m^3+\left(3+18\theta_r+46\theta_r^2+58\theta_r^3+28\theta_r^4\right)\theta_m^4\right)\right)\gamma\right)\right)}{b^2(-1+\theta_r)^2\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^2\gamma} > 0, \tag{B.47}$$

$$\frac{\partial w_2^{AAI}}{\partial\theta_r} = \frac{\left(c^2(-1+\theta_m)\left(-51+3(7+44\theta_r)\theta_m+\left(4-50\theta_r-107\theta_r^2\right)\theta_m^2+\left(-2+2\theta_r+23\theta_r^2+28\theta_r^3\right)\theta_m^3\right)+2b\left(2a(-1+\theta_m)\left(-51+3(7+44\theta_r)\theta_m+\left(4-50\theta_r-107\theta_r^2\right)\theta_m^2+\left(-2+2\theta_r+23\theta_r^2+28\theta_r^3\right)\theta_m^3\right)+bh\left(170-40(6+11\theta_r)\theta_m+\left(121+478\theta_r+421\theta_r^2\right)\theta_m^2-2\left(13+82\theta_r+157\theta_r^2+88\theta_r^3\right)\theta_m^3+\left(2+18\theta_r+55\theta_r^2+68\theta_r^3+27\theta_r^4\right)\theta_m^4\right)\right)\gamma\right)}{2b^2(-1+\theta_r)^2\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma} > 0, \tag{B.48}$$

Solving

$$\begin{aligned}\frac{\partial Q_1^{AAI}}{\partial \theta_r} = {} & (\theta_m (c^2 (-1+\theta_m)^3 \big(193 - 4(70+123\theta_r)\theta_m + 6\big(26+88\theta_r+79{\theta_r}^2\big){\theta_m}^2 - 4\big(10+48\theta_r+84{\theta_r}^2+51{\theta_r}^3\big){\theta_m}^3 \\ & + \big(4+24\theta_r+60{\theta_r}^2+72{\theta_r}^3+33{\theta_r}^4\big){\theta_m}^4\big) - 2b(-2a*(-1+\theta_m)^3 \\ & \cdot \big(193 - 4(70+123\theta_r)\theta_m + 6\big(26+88\theta_r+79{\theta_r}^2\big){\theta_m}^2 - 4\big(10+48\theta_r+84{\theta_r}^2+51{\theta_r}^3\big){\theta_m}^3 \\ & + \big(4+24\theta_r+60{\theta_r}^2+72{\theta_r}^3+33{\theta_r}^4\big){\theta_m}^4\big) + bh(-2+\theta_m+\theta_r\theta_m)^2 \\ & * (-335 + 67(11+14\theta_r)\theta_m - 2\big(314+846\theta_r+515{\theta_r}^2\big){\theta_m}^2 + 2\big(130+552\theta_r+717{\theta_r}^2+276{\theta_r}^3\big){\theta_m}^3 \\ & - \big(52+312\theta_r+636{\theta_r}^2+532{\theta_r}^3+143{\theta_r}^4\big){\theta_m}^4 + (4+32\theta_r+92{\theta_r}^2 \\ & + 120{\theta_r}^3+73{\theta_r}^4+14{\theta_r}^5){\theta_m}^5))\gamma))/\big(4b(-1+\theta_m)^2(-34+(41+61\theta_r)\theta_m \\ & - 2\big(8+25\theta_r+18{\theta_r}^2\big){\theta_m}^2 + \big(2+10\theta_r+15{\theta_r}^2+7{\theta_r}^3\big){\theta_m}^3)^2\gamma) = 0, \end{aligned} \tag{B.49}$$

reveals thresholds of h, when $0.154 < \theta_m < 1$, $0 < \theta_r < f_5(\theta_m)$, $h_{rQ_1}^{AA} < h < h^{AA}$, $\partial Q_1^{AAI}/\partial \theta_r > 0$.

$$h_{rQ_1}^{AA} = \frac{\left((-1+\theta_m)^3\begin{pmatrix}193 - 4(70+123\theta_r)\theta_m + 6\big(26+88\theta_r+79\theta_r^2\big)\theta_m^2 \\ -4\big(10+48\theta_r+84\theta_r^2+51\theta_r^3\big)\theta_m^3 + \big(4+24\theta_r+60\theta_r^2+72\theta_r^3+33\theta_r^4\big)\theta_m^4\end{pmatrix}\big(c^2+4ab\gamma\big)\right)}{\left(2b^2*(-2+\theta_m+\theta_r\theta_m)^2\begin{pmatrix}-335+67(11+14\theta_r)\theta_m - 2\big(314+846\theta_r+515\theta_r^2\big)\theta_m^2 \\ +2\big(130+552\theta_r+717\theta_r^2+276\theta_r^3\big)\theta_m^3 - \big(52+312\theta_r+636\theta_r^2+532\theta_r^3+143\theta_r^4\big)\theta_m^4 \\ +\big(4+32\theta_r+92\theta_r^2+120\theta_r^3+73\theta_r^4+14\theta_r^5\big)\theta_m^5\end{pmatrix}\gamma\right)}, \tag{B.50}$$

$$f_5(\theta_m) \to -\frac{1}{6\theta_m}\left(\begin{matrix} -10+4\theta_m+\sqrt{2}\,\theta_m\sqrt{\left(\dfrac{\left(\begin{matrix}-32*2^{(1/3)}\theta_m^5+48*2^{(1/3)}\theta_m^6-32*2^{(1/3)}\theta_m^7+8*2^{(1/3)}\theta_m^8+12\theta_m^2C_8^{(1/3)}- \\ 24\theta_m^3C_8^{(1/3)}+\begin{pmatrix}-238\theta_m^6+1428\theta_m^7-3570\theta_m^8+4760\theta_m^9-3570\theta_m^{10}+1428\theta_m^{11}- \\ 238\theta_m^{12}+6\sqrt{1545}\sqrt{(-1+\theta_m)^{12}\theta_m^{12}}\end{pmatrix}^{(2/3)} + 4\theta_m^4\big(2*2^{(1/3)}+3C_8^{(1/3)}\big)\end{matrix}\right)}{\big(\theta_m^4C_8^{(1/3)}\big)}\right)} \\ +\sqrt{2}\,\theta_m\sqrt{\left(\begin{matrix}8-\big(76/\theta_m^2\big)+\dfrac{\big(4(5-2\theta_m)^2\big)}{\theta_m^2}+\dfrac{32}{\theta_m}-\dfrac{\big(8*2^{(1/3)}(-1+\theta_m)^4\big)}{C_8^{(1/3)}}-\dfrac{\big(2^{(2/3)}C_8^{(1/3)}\big)}{\theta_m^5}+ \\ \dfrac{\big(20\sqrt{2}(-1+\theta_m)^3\big)}{\left(\theta_m^3\sqrt{\left(\left(\begin{matrix}-32*2^{(1/3)}\theta_m^5+48*2^{(1/3)}\theta_m^6-32*2^{(1/3)}\theta_m^7+8*2^{(1/3)}\theta_m^8+12\theta_m^2C_8^{(1/3)}- \\ 24\theta_m^3C_8^{(1/3)}+\begin{pmatrix}-238\theta_m^6+1428\theta_m^7-3570\theta_m^8+4760\theta_m^9-3570\theta_m^{10}+ \\ 1428\theta_m^{11}-238\theta_m^{12}+6\sqrt{1545}\sqrt{(-1+\theta_m)^{12}\theta_m^{12}}\end{pmatrix}^{(2/3)} \\ +4\theta_m^4\big(2*2^{(1/3)}+3C_8^{(1/3)}\big)\end{matrix}\right)/\big(\theta_m^4C_8^{(1/3)}\big)\right)}\right)}\end{matrix}\right)}\end{matrix}\right), \tag{B.51}$$

$$\frac{\partial q_1^{AAI}}{\partial\theta_r}=\frac{\left(\theta_m\left(c^2(-1+\theta_m)^2\left(141-188(1+2\theta_r)\theta_m+\left(95+374\theta_r+377\theta_r^2\right)\theta_m^2-2\left(11+62\theta_r+125\theta_r^2+84\theta_r^3\right)\theta_m^3+\left(2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4\right)\theta_m^4\right)+2b\left(-bh(-2+\theta_m+\theta_r\theta_m)^2\left(95-4(37+58\theta_r)\theta_m+3\left(29+90\theta_r+71\theta_r^2\right)\theta_m^2-2\left(11+54\theta_r+81\theta_r^2+44\theta_r^3\right)\theta_m^3+\left(2+14\theta_r+33\theta_r^2+32\theta_r^3+14\theta_r^4\right)\theta_m^4\right)+2a(-1+\theta_m)^2\left(141-188(1+2\theta_r)\theta_m+\left(95+374\theta_r+377\theta_r^2\right)\theta_m^2-2\left(11+62\theta_r+125\theta_r^2+84\theta_r^3\right)\theta_m^3-\left(2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4\right)\theta_m^4\right)\right)\gamma\right)\right)}{4b(-1+\theta_m)\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^2\gamma}<0, \tag{B.52}$$

$$\frac{\partial p_1^{AAI}}{\partial\theta_r}=-\frac{\left(\theta_m\left(c^2(-1+\theta_m)^2\begin{pmatrix}141-188(1+2\theta_r)\theta_m+\left(95+374\theta_r+377\theta_r^{2}\right)\theta_m^{2}-\\ 2\left(11+62\theta_r+125\theta_r^{2}+84\theta_r^{3}\right)\theta_m^{3}+\\ \left(2+14\theta_r+41\theta_r^{2}+56\theta_r^{3}+28\theta_r^{4}\right)\theta_m^{4}\end{pmatrix}+2b\left(\begin{matrix}-bh(-2+\theta_m+\theta_r\theta_m)^2\begin{pmatrix}95-4(37+58\theta_r)\theta_m+3\left(29+90\theta_r+71\theta_r^{2}\right)\theta_m^{2}-\\ 2\left(11+54\theta_r+81\theta_r^{2}+44\theta_r^{3}\right)\theta_m^{3}+\left(2+14\theta_r+33\theta_r^{2}+32\theta_r^{3}+14\theta_r^{4}\right)\theta_m^{4}\end{pmatrix}+\\ 2a(-1+\theta_m)^2\begin{pmatrix}141-188(1+2\theta_r)\theta_m+\left(95+374\theta_r+377\theta_r^{2}\right)\theta_m^{2}-\\ 2\left(11+62\theta_r+125\theta_r^{2}+84\theta_r^{3}\right)\theta_m^{3}+\left(2+14\theta_r+41\theta_r^{2}+56\theta_r^{3}+28\theta_r^{4}\right)\theta_m^{4}\end{pmatrix}\end{matrix}\right)\gamma\right)\right)}{\left(4b^2(-1+\theta_m)\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^{2}\right)\theta_m^{2}+\left(2+10\theta_r+15\theta_r^{2}+7\theta_r^{3}\right)\theta_m^{3}\right)^2\gamma\right)}>0, \tag{B.53}$$

Solving

$$\frac{\partial I^{AAI}}{\partial\theta_r}=\frac{\left(\theta_m\left(c^2(-1+\theta_m)^3 13-2(5+8\theta_r)\theta_m+\left(2+6\theta_r+5\theta_r^2\right)\theta_m^2-2b\left(-2a(-1+\theta_m)^3\left(13-2(5+8\theta_r)\theta_m+\left(2+6\theta_r+5\theta_r^2\right)\theta_m^2\right)+bh\left(-240+(494+706\theta_r)\theta_m-\left(393+1190\theta_r+817\theta_r^2\right)\theta_m^2+\left(151+726\theta_r+1059\theta_r^2+464\theta_r^3\right)\theta_m^3-\left(28+190\theta_r+441\theta_r^2+412\theta_r^3+129\theta_r^4\right)\theta_m^4+\left(2+18\theta_r+59\theta_r^2+88\theta_r^3+59\theta_r^4+14\theta_r^5\right)\theta_m^5\right)\right)\gamma\right)\right)}{4b(-1+\theta_m)^2\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma}=0. \tag{B.54}$$

reveals thresholds of h, when $h_{rI}^{AA} < h < h^{AA}$, $\partial I^{AAI}/\partial\theta_r > 0$

$$h_{rI}^{AA}=\frac{(-1+\theta_m)^3\left(13-2(5+8\theta_r)\theta_m+\left(2+6\theta_r+5\theta_r^2\right)\theta_m^2\right)\left(c^2+4ab\gamma\right)}{2b^2\left(-240+(494+706\theta_r)\theta_m-\left(393+1190\theta_r+817\theta_r^2\right)\theta_m^2+\left(151+726\theta_r+1059\theta_r^2+464\theta_r^3\right)\theta_m^3-\left(28+190\theta_r+441\theta_r^2+412\theta_r^3+129\theta_r^4\right)\theta_m^4+\left(2+18\theta_r+59\theta_r^2+88\theta_r^3+59\theta_r^4+14\theta_r^5\right)\theta_m^5\right)\gamma}, \tag{B.55}$$

$$\frac{\partial Q_2^{AAI}}{\partial\theta_r}=\frac{\theta_m\left(c^2(-1+\theta_m)^3\left(19-2(6+13\theta_r)\theta_m+\left(2+8\theta_r+9\theta_r^2\right)\theta_m^2\right)+2b\left(2a(-1+\theta_m)^3\left(19-2(6+13\theta_r)\theta_m+\left(2+8\theta_r+9\theta_r^2\right)\theta_m^2\right)+bh\left(-205+(417+608\theta_r)\theta_m-\left(335+998\theta_r+717\theta_r^2\right)\theta_m^2+\left(133+606\theta_r+891\theta_r^2+420\theta_r^3\right)\theta_m^3-\left(26+162\theta_r+363\theta_r^2+352\theta_r^3+122\theta_r^4\right)\theta_m^4+\left(2+16\theta_r+49\theta_r^2+72\theta_r^3+52\theta_r^4+14\theta_r^5\right)\theta_m^5\right)\right)\gamma\right)}{4b(-1+\theta_m)^2\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma}<0, \tag{B.56}$$

$$\frac{\partial q_2^{AAI}}{\partial\theta_r}=\frac{\left(\theta_m\left(c^2(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)+b\left(4a(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)-bh\left(35-14(3+7\theta_r)\theta_m+2\left(8+47\theta_r+50\theta_r^2\right)\theta_m^2-2\left(1+13\theta_r+34\theta_r^2+22\theta_r^3\right)\theta_m^3+\theta_r\left(2+10\theta_r+16\theta_r^2+7\theta_r^3\right)\theta_m^4\right)\right)\gamma\right)\right)}{2b(-1+\theta_m)\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma}<0, \tag{B.57}$$

$$\frac{\partial p_2^{AAI}}{\partial\theta_r}=-\frac{\left(\theta_m\left(c^2(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)+b\left(4a(-1+\theta_m)^2\right)\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)-bh\left(35-14(3+7\theta_r)\theta_m+2\left(8+47\theta_r+50\theta_r^2\right)\theta_m^2-2\left(1+13\theta_r+34\theta_r^2+22\theta_r^3\right)\theta_m^3+\theta_r\left(2+10\theta_r+16\theta_r^2+7\theta_r^3\right)\theta_m^4\right)\right)\gamma\right)}{2b^2(-1+\theta_m)\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma}>0. \tag{B.58}$$

(3) In scenario RAN,

$$\begin{aligned}&\frac{\partial w_1^{RAN}}{\partial\theta_r}=\frac{\partial w_2^{RAN}}{\partial\theta_r}=\frac{c^2+4ab\gamma}{8b^2(-1+\theta_r)^2\gamma}>0,\\ &\frac{\partial e^{RAN}}{\partial\theta_r}=\frac{\partial Q_1^{RAN}}{\partial\theta_r}=\frac{\partial Q_2^{RAN}}{\partial\theta_r}=\frac{\partial q_1^{RAN}}{\partial\theta_r}=\frac{\partial p_1^{RAN}}{\partial\theta_r}=\frac{\partial q_2^{RAN}}{\partial\theta_r}=\frac{\partial p_2^{RAN}}{\partial\theta_r}=0.\end{aligned} \tag{B.59}$$

(4) In scenario AAN,

$$\begin{aligned}
&\frac{\partial e^{AAN}}{\partial \theta_r} = 0,\\
&\frac{\partial w_1^{AAN}}{\partial \theta_r} = \frac{\partial w_2^{AAN}}{\partial \theta_r} = \frac{(-1+\theta_m)(-1+\theta_r\theta_m)\left(c^2+4ab\gamma\right)}{2b^2(-1+\theta_r)^2(-2+\theta_m+\theta_r\theta_m)^2\gamma} > 0,\\
&\frac{\partial Q_1^{AAN}}{\partial \theta_r} = \frac{\partial Q_2^{AAN}}{\partial \theta_r} = \frac{\partial q_1^{AAN}}{\partial \theta_r} = \frac{\partial q_2^{AAN}}{\partial \theta_r} = \frac{(-1+\theta_m)\theta_m\left(c^2+4ab\gamma\right)}{8b(-2+\theta_m+\theta_r\theta_m)^2\gamma} < 0,\\
&\frac{\partial p_1^{AAN}}{\partial \theta_r} = \frac{\partial p_2^{AAN}}{\partial \theta_r} = -\frac{(-1+\theta_m)\theta_m\left(c^2+4ab\gamma\right)}{8b^2(-2+\theta_m+\theta_r\theta_m)^2\gamma} > 0.
\end{aligned} \tag{B.60}$$

□

Proof of Proposition 6.

To explore the impact of the retailer's altruistic preference on profits, we compare four different scenarios (RAI, AAI, RAN, and AAN).

(1) In scenario RAI,

$$\begin{aligned}
&\frac{\partial \Pi_r^{RAI}}{\partial \theta_r} = \frac{-9c^4+8bc^2(-9a+2bh)\gamma-16b^2\left(9a^2-4abh+8b^2h^2\right)\gamma^2}{544b^3(-1+\theta_r)^2\gamma^2} < 0,\\
&\frac{\partial \Pi_m^{RAI}}{\partial \theta_r} = \frac{9c^4+8bc^2(9a-2bh)\gamma+16b^2\left(9a^2-4abh+8b^2h^2\right)\gamma^2}{544b^3(-1+\theta_r)^2\gamma^2} > 0,\\
&\frac{\partial \Pi^{RAI}}{\partial \theta_r} = 0.
\end{aligned} \tag{B.61}$$

(2) In scenario AAI,

$$\frac{\partial \Pi_r^{AAI}}{\partial \theta_r} = -\frac{\left(\begin{gathered} \left(c^4(-1+\theta_m)^4 C_9 + 4bc^2(-1+\theta_m)^3 \left(\begin{gathered} -bh(-2+\theta_m+\theta_r\theta_m)^3 \left(\begin{gathered} 289+6\left(-60-271\theta_r+42\theta_r^2\right)\theta_m + \\ \left(184+1975\theta_r+2893\theta_r^2-717\theta_r^3\right)\theta_m^2 + \\ 4\left(-11-256\theta_r-793\theta_r^2-577\theta_r^3+192\theta_r^4\right)\theta_m^3 + \\ \left(4+271\theta_r+1372\theta_r^2+2180\theta_r^3+875\theta_r^4-367\theta_r^5\right)\theta_m^4 + \\ 2\theta_r\left(-18-135\theta_r-344\theta_r^2-332\theta_r^3-71\theta_r^4+33\theta_r^5\right)\theta_m^5 + \\ \theta_r\left(2+20\theta_r+73\theta_r^2+116\theta_r^3+71\theta_r^4+7\theta_r^5\right)\theta_m^6 \end{gathered} \right) + \\ 2a(-1+\theta_m)C_9 \end{gathered} \right) \right)\gamma + \\ 4b^2 \left(\begin{gathered} -4abh(-1+\theta_m)^3(-2+\theta_m+\theta_r\theta_m)^3 \left(\begin{gathered} 289+6\left(-60-271\theta_r+42\theta_r^2\right)\theta_m + \\ \left(184+1975\theta_r+2893\theta_r^2-717\theta_r^3\right)\theta_m^2 + \\ 4\left(-11-256\theta_r-793\theta_r^2-577\theta_r^3+192\theta_r^4\right)\theta_m^3 + \\ \left(4+271\theta_r+1372\theta_r^2+2180\theta_r^3+875\theta_r^4-367\theta_r^5\right)\theta_m^4 + \\ 2\theta_r\left(-18-135\theta_r-344\theta_r^2-332\theta_r^3-71\theta_r^4+33\theta_r^5\right)\theta_m^5 + \\ \theta_r\left(2+20\theta_r+73\theta_r^2+116\theta_r^3+71\theta_r^4+7\theta_r^5\right)\theta_m^6 \end{gathered} \right) - \\ b^2h^2(-2+\theta_m+\theta_r\theta_m)^4 \left(\begin{gathered} -1156+\left(3378+7830\theta_r-1960\theta_r^2\right)\theta_m+2\left(-1986-11212\theta_r-6485\theta_r^2+3499\theta_r^3\right)\theta_m^2 + \\ \left(2384+26126\theta_r+424420\theta_r^2+40800\theta_r^3-102740\theta_r^4\right)\theta_m^3 + \\ 2\left(-382-7976\theta_r-23641\theta_r^2-16721\theta_r^3+4304\theta_r^4+3956\theta_r^5\right)\theta_m^4 + \\ \left(124+5519\theta_r+257793\theta_r^2+368898\theta_r^3+96080\theta_r^4-98550\theta_r^5-3351\theta_r^6\right)\theta_m^5 + \\ \left(-8-1103\theta_r-7419\theta_r^2-17032\theta_r^3-13222\theta_r^4+1413\theta_r^5+4271\theta_r^6+732\theta_r^7\right)\theta_m^6 \\ +\theta_r\left(122+1092\theta_r+3563\theta_r^2+4863\theta_r^3+1790\theta_r^4-1310\theta_r^5-809\theta_r^6-63\theta_r^7\right)\theta_m^7 + \\ \theta_r\left(-6-66\theta_r-281\theta_r^2-563\theta_r^3-476\theta_r^4-2\theta_r^5+189\theta_r^6+49\theta_r^7\right)\theta_m^8 \end{gathered} \right) + 4a^2(-1+\theta_m)^4 C_9 \end{gathered} \right)\gamma^2 \end{gathered} \right)}{\left(8b^3(-1+\theta_r)^2(-1+\theta_m)^3\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^3\gamma^2\right)} < 0$$

$$\frac{\partial \Pi_m^{AAI}}{\partial \theta_r} = \frac{\left(\begin{gathered} \left(c^4(-1+\theta_m)^4 C_{10} + 4bc^2(-1+\theta_m)^3 \left(\begin{gathered} -bh(-2+\theta_m+\theta_r\theta_m)^3 \\ \left(\begin{gathered} 289-102(6+11\theta_r)\theta_m+\left(727+1606\theta_r+2002\theta_r^2\right)\theta_m^2 - \\ 4\left(116+379\theta_r+424\theta_r^2+526\theta_r^3\right)\theta_m^3 + \\ 3\left(53+252\theta_r+380\theta_r^2+312\theta_r^3+448\theta_r^4\right)\theta_m^4 - \\ 2\left(14+89\theta_r+200\theta_r^2+180\theta_r^3+144\theta_r^4+240\theta_r^5\right)\theta_m^5 + \\ \left(2+16\theta_r+49\theta_r^2+68\theta_r^3+39\theta_r^4+42\theta_r^5+73\theta_r^6\right)\theta_m^6 \end{gathered} \right) \end{gathered} + 2a(-1+\theta_m)C_{10} \right) \right)\gamma + \\ 4b^2 \left(\begin{gathered} -4abh(-1+\theta_m)^3(-2+\theta_m+\theta_r\theta_m)^3 \left(\begin{gathered} 289-102(6+11\theta_r)\theta_m+\left(727+1606\theta_r+2002\theta_r^2\right)\theta_m^2 - \\ 4\left(116+379\theta_r+424\theta_r^2+526\theta_r^3\right)\theta_m^3 + \\ 3\left(53+252\theta_r+380\theta_r^2+312\theta_r^3+448\theta_r^4\right)\theta_m^4 - \\ 2\left(14+89\theta_r+200\theta_r^2+180\theta_r^3+144\theta_r^4+240\theta_r^5\right)\theta_m^5 + \\ \left(2+16\theta_r+49\theta_r^2+68\theta_r^3+39\theta_r^4+42\theta_r^5+73\theta_r^6\right)\theta_m^6 \end{gathered} \right) + \\ b^2h^2(-2+\theta_m+\theta_r\theta_m)^4 \left(\begin{gathered} 1156-34(157+115\theta_r)\theta_m+2\left(5347+7989\theta_r+2848\theta_r^2\right)\theta_m^2 - \\ 2\left(5915+143337\theta_r+9630\theta_r^2+2486\theta_r^3\right)\theta_m^3 + \\ 2\left(3926+13871\theta_r+15036\theta_r^2+6026\theta_r^3+1601\theta_r^4\right)\theta_m^4 - \\ \left(3207+15373\theta_r+24738\theta_r^2+15358\theta_r^3+4373\theta_r^4+1687\theta_r^5\right)\theta_m^5 + \\ (787+48899\theta_r+108812\theta_r^2+103222\theta_r^3+3777\theta_r^4+1113\theta_r^5+658\theta_r^6)\theta_m^6 - \\ \left(106+832\theta_r+2403\theta_r^2+3203\theta_r^3+1958\theta_r^4+336\theta_r^5+259\theta_r^6+151\theta_r^7\right)\theta_m^7 + \\ \left(6+58\theta_r+213\theta_r^2+375\theta_r^3+332\theta_r^4+126\theta_r^5-7\theta_r^6+39\theta_r^7+14\theta_r^8\right)\theta_m^8 \end{gathered} \right) + 4a^2(-1+\theta_m)^4 C_{10} \end{gathered} \right)\gamma^2 \end{gathered} \right)}{\left(8b^3(-1+\theta_r)^2(-1+\theta_m)^3\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^3\gamma^2\right)} > 0$$

$$\frac{\partial \Pi^{AAI}}{\partial \theta_r} = \frac{\left(\theta_m \left(\begin{gathered} c^4(-1+\theta_m)^4 C_{11} + \\ 4bc^2(-1+\theta_m)^3(-3+\theta_m+2\theta_r\theta_m) \\ \left(\begin{gathered} -bh(-2+\theta_m+\theta_r\theta_m)^3\left(-84+3(23+61\theta_r)\theta_m-2\left(10+49\theta_r+67\theta_r^2\right)\theta_m^2+\left(2+14\theta_r+35\theta_r^2+33\theta_r^3\right)\theta_m^3\right) + \\ 2a(-1+\theta_m)\left(\begin{gathered} -679+5(253+426\theta_r)\theta_m-\left(961+3138\theta_r+2691\theta_r^2\right)\theta_m^2+\left(373+1764\theta_r+2943\theta_r^2+1710\theta_r^3\right)\theta_m^3 - \\ \left(74+450\theta_r+1089\theta_r^2+1236\theta_r^3+546\theta_r^4\right)\theta_m^4+\left(6+44\theta_r+137\theta_r^2+226\theta_r^3+196\theta_r^4+70\theta_r^5\right)\theta_m^5 \end{gathered} \right) \end{gathered} \right)\gamma + \\ 4b^2 \left(\begin{gathered} -4abh(-1+\theta_m)^3(-2+\theta_m+\theta_r\theta_m)^3 \left(\begin{gathered} 252-3(97+239\theta_r)\theta_m+3\left(43+205\theta_r+256\theta_r^2\right)\theta_m^2 - \\ \left(26+180\theta_r+435\theta_r^2+367\theta_r^3\right)\theta_m^3+\left(2+18\theta_r+63\theta_r^2+103\theta_r^3+66\theta_r^4\right)\theta_m^4 \end{gathered} \right) + \\ b^2h^2(-2+\theta_m+\theta_r\theta_m)^4 \\ \left(\begin{gathered} 1960-2(2381+3499\theta_r)\theta_m+2\left(2342+7221\theta_r+5137\theta_r^2\right)\theta_m^2-4\left(601+2881\theta_r+4340\theta_r^2+1978\theta_r^3\right)\theta_m^3 + \\ \left(679+4496\theta_r+10542\theta_r^2+10332\theta_r^3+3351\theta_r^4\right)\theta_m^4-2\left(50+429\theta_r+1390\theta_r^2+2124\theta_r^3+1521\theta_r^4+366\theta_r^5\right)\theta_m^5 \\ +\left(6+64\theta_r+269\theta_r^2+568\theta_r^3+636\theta_r^4+354\theta_r^5+63\theta_r^6\right)\theta_m^6 \end{gathered} \right) + \\ 4a^2(-1+\theta_m)^4 C_{11} \end{gathered} \right)\gamma^2 \end{gathered} \right) \right)}{8b^3(-1+\theta_m)^2\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^3\gamma^2} < 0$$

$$C_9 = \begin{pmatrix} 5202 + 3\left(-3860 - 106910_r + 679\theta_r^2\right)\theta_m + \left(10842 + 658870_r + 76675\theta_r^2 - 7748\theta_r^3\right)\theta_m^2 \\ +3\left(-1824 - 190860_r - 475640_r^2 - 327410_r^3 + 4111\theta_r^4\right)\theta_m^3 + 3\left(524 + 91000_r + 36060\theta_r^2 + 538450_r^3 + 253550_r^4 - 3504\theta_r^5\right) \\ \theta_m^4 + \left(-244 - 77430_r - 435450_r^2 - 1012900_r^3 - 1061300_r^4 - 374180_r^5 + 5058\theta_r^6\right) \\ \theta_m^5 + \left(16 + 13230_r + 9915 * \theta_r^2 + 315400_r^3 + 512400_r^4 + 411840_r^5 + 117400_r^6 - 1302\theta_r^7\right) \\ \theta_m^6 + \theta_r\left(-130 - 12280_r - 49470_r^2 - 108550_r^3 - 135220_r^4 - 88620_r^5 - 22120_r^6 + 140\theta_r^7\right) \\ \theta_m^7 + \theta_r\left(6 + 66\theta_r + 317\theta_r^2 + 867\theta_r^3 + 1452\theta_r^4 + 1472\theta_r^5 + 826\theta_r^6 + 196\theta_r^7\right)\theta_m^8 \end{pmatrix}, \tag{B.62}$$

$$C_{10} = \begin{pmatrix} 5202 - 153\left(89 + 183\theta_r\right)\theta_m + 7\left(2479 + 8659\theta_r + 9670\theta_r^2\right) \\ \theta_m^2 - 3\left(4698 + 206120_r + 40001\theta_r^2 + 31793\theta_r^3\right) \\ \theta_m^3 + 15\left(520 + 2618\theta_r + 6379\theta_r^2 + 9081\theta_r^3 + 5678\theta_r^4\right) \\ \theta_m^4 - \left(2919 + 166050_r + 453300_r^2 + 822500_r^3 + 950900_r^4 + 491180_r^5\right) \\ \theta_m^5 + \left(703 + 4539\theta_r + 13560\theta_r^2 + 27250\theta_r^3 + 41250\theta_r^4 + 40554\theta_r^5 + 17800 * \theta_r^6\right) \\ \theta_m^6 - \left(98 + 720\theta_r + 2379\theta_r^2 + 5075\theta_r^3 + 8550\theta_r^4 + 11370\theta_r^5 + 9728\theta_r^6 + 3696\theta_r^7\right) \\ \theta_m^7 + \left(6 + 50\theta_r + 185\theta_r^2 + 423\theta_r^3 + 740\theta_r^4 + 1118\theta_r^5 + 1336\theta_r^6 + 1008\theta_r^7 + 336\theta_r^8\right)\theta_m^8 \end{pmatrix}, \tag{B.63}$$

$$\begin{aligned} C_{11} = {} & \left(2037 - 2\left(2237 + 3874\theta_r\right)\theta_m + \left(4148 + 14074\theta_r + 12333\theta_r^2\right)\theta_m^2 - 4\left(520 + 2588\theta_r + 4449\theta_r^2 + 2628\theta_r^3\right)\theta_m^3 \right. \\ & + \left(595 + 3860\theta_r + 9738\theta_m^2 + 11304\theta_r^3 + 5058\theta_r^4\right)\theta_m^4 - 2\left(46 + 365\theta_r + 1200\theta_r^2 + 2046\theta_r^3 + 1803\theta_r^4 + 651\theta_r^5\right)\theta_m^5 \\ & \left. + \left(6 + 56\theta_r + 225\theta_r^2 + 500\theta_r^3 + 648\theta_r^4 + 462\theta_r^5 + 140\theta_r^6\right)\theta_m^6\right). \end{aligned} \tag{B.64}$$

(3) In scenario RAN,

$$\begin{aligned} \frac{\partial \prod_r^{RAN}}{\partial\theta_r} &= -\frac{\left(c^2 + 4ab\gamma\right)^2}{64b^3\left(-1 + \theta_r\right)^2\gamma^2} < 0, \\ \frac{\partial \prod_m^{RAN}}{\partial\theta_r} &= \frac{\left(c^2 + 4ab\gamma\right)^2}{64b^3\left(-1 + \theta_r\right)^2\gamma^2} > 0, \\ \frac{\partial \prod^{RAN}}{\partial\theta_r} &= 0. \end{aligned} \tag{B.65}$$

(4) In scenario AAN,

$$\begin{aligned} \frac{\partial \Pi_r^{AAN}}{\partial\theta_r} &= -\frac{\left(-1 + \theta_m\right)\left(2 + \theta_r\left(-5 + \theta_m\right)\theta_m + \theta_r^2\theta_m\left(1 + \theta_m\right)\right)\left(c^2 + 4ab\gamma\right)^2}{16b^3\left(-1 + \theta_r\right)^2\left(-2 + \theta_m + \theta_r\theta_m\right)^3\gamma^2} < 0, \\ \frac{\partial \Pi_m^{AAN}}{\partial\theta_r} &= \frac{\left(-1 + \theta_m\right)\left(2 - \left(1 + 3\theta_r\right)\theta_m + \left(1 - \theta_r + 2\theta_r^2\right)\theta_m^2\right)\left(c^2 + 4ab\gamma\right)^2}{16b^3\left(-1 + \theta_r\right)^2\left(-2 + \theta_m + \theta_r\theta_m\right)^3\gamma^2} > 0, \end{aligned} \tag{B.66}$$

$$\frac{\partial \Pi^{AAN}}{\partial\theta_r} = \frac{\left(-1 + \theta_m\right)^2\theta_m\left(c^2 + 4ab\gamma\right)^2}{16b^3\left(-2 + \theta_m + \theta_r\theta_m\right)^3\gamma^2} < 0, \tag{B.67}$$

□

Proof of Proposition 7.

To explore the impact of the manufacturer's altruistic preference, we compare decisions under four different scenarios (ARI, AAI, ARN, and AAN).

(1) In scenario ARI,

$$\frac{\partial e^{ARI}}{\partial \theta_m} = 0, \tag{B.68}$$

$$\frac{\partial w_1^{ARI}}{\partial \theta_m} = -\frac{c^2(-1+\theta_m)^2\left(141-188\theta_m+95\theta_m^2-22\theta_m^3+2\theta_m^4\right)+2b\begin{pmatrix}-bh(-2+\theta_m)^2\left(95-148\theta_m+87\theta_m^2-22\theta_m^3+2\theta_m^4\right)+\\ 2a(-1+\theta_m)^2\left(141-188\theta_m+95\theta_m^2-22\theta_m^3+2\theta_m^4\right)\end{pmatrix}\gamma}{2b^2(-1+\theta_m)^2\left(34-41\theta_m+16\theta_m^2-2\theta_m^3\right)^2\gamma} < 0, \tag{B.69}$$

$$\frac{\partial w_2^{ARI}}{\partial \theta_m} = \frac{-c^2(-1+\theta_m)^2\left(16-11\theta_m+2\theta_m^2\right)+b\left(-4a(-1+\theta_m)^2\left(16-11\theta_m+2\theta_m^2\right)+bh\left(35-42\theta_m+16\theta_m^2-2\theta_m^3\right)\right)\gamma}{b^2(-1+\theta_m)^2\left(17-12\theta_m+2\theta_m^2\right)^2\gamma} < 0. \tag{B.70}$$

Solving

$$\frac{\partial Q_1^{ARI}}{\partial \theta_m} = \frac{c^2(-1+\theta_m)^3\left(193-280\theta_m+156\theta_m^2-40\theta_m^3+4\theta_m^4\right)+2b\left(2a(-1+\theta_m)^3\left(193-280\theta_m+156\theta_m^2-40\theta_m^3+4\theta_m^4\right)-bh(-2+\theta_m)^2\left(-335+737\theta_m-628\theta_m^2+260\theta_m^3-52\theta_m^4+4\theta_m^5\right)\right)\gamma}{4b(-2+\theta_m)^2(-1+\theta_m)^3\left(17-12\theta_m+2\theta_m^2\right)^2\gamma} = 0, \tag{B.71}$$

reveals the threshold of h, when $0 < h < h_{mQ_1}^{AR}$, $\partial Q_1^{ARI}/\partial \theta_m > 0$

$$h_{mQ_1 1}^{AR} = \begin{cases} h^{AR}, & 0 < \theta_m < 0.154, \\ h_{mQ_1 1}^{AR}, & 0.154 < \theta_m < 1, \end{cases}$$
$$h_{mQ_1 1}^{AR} = \frac{(-1+\theta_m)^3\left(193-280\theta_m+156\theta_m^2-40\theta_m^3+4\theta_m^4\right)\left(c^2+4ab\gamma\right)}{2b^2(-2+\theta_m)^2\left(-335+737\theta_m-628\theta_m^2+260\theta_m^3-52\theta_m^4+4\theta_m^5\right)\gamma}, \tag{B.72}$$

$$\frac{\partial q_1^{ARI}}{\partial \theta_m} = \frac{c^2(-1+\theta_m)^2\left(141-188\theta_m+95\theta_m^2-22\theta_m^3+2\theta_m^4\right)+2b\left(-bh(-2+\theta_m)^2\left(95-148\theta_m+87\theta_m^2-22\theta_m^3+2\theta_m^4\right)+2a(-1+\theta_m)^2\left(141-188\theta_m+95\theta_m^2-22\theta_m^3+2\theta_m^4\right)\right)\gamma}{4b(-1+\theta_m)^2\left(34-41\theta_m+16\theta_m^2-2\theta_m^3\right)^2\gamma} > 0, \tag{B.73}$$

$$\frac{\partial p_1^{ARI}}{\partial \theta_m} = -\frac{c^2(-1+\theta_m)^2\left(141-188\theta_m+95\theta_m^2-22\theta_m^3+2\theta_m^4\right)+2b\left(-bh(-2+\theta_m)^2\left(95-148\theta_m+87\theta_m^2-22\theta_m^3+2\theta_m^4\right)+2a(-1+\theta_m)^2\left(141-188\theta_m+95\theta_m^2-22\theta_m^3+2\theta_m^4\right)\right)\gamma}{4b^2(-1+\theta_m)^2\left(34-41\theta_m+16\theta_m^2-2\theta_m^3\right)^2\gamma} < 0. \tag{B.74}$$

Solving $\partial I^{ARI}/\partial \theta_m = \left(c^2(-1+\theta_m)^3(13-10\theta_m+2{\theta_m}^2)+2b\begin{pmatrix}2a(-1+\theta_m)^3(13-10\theta_m+2{\theta_m}^2)+\\ bh(240-494\theta_m+393{\theta_m}^2-151{\theta_m}^3+28{\theta_m}^4-2{\theta_m}^5)\end{pmatrix}\gamma\right)/\begin{pmatrix}4b(-1+\theta_m)^3\\ (17-12\theta_m+2{\theta_m}^2)^2\gamma\end{pmatrix} = 0$ reveals the threshold of h, when $0 < h < h_{mI}^{AR} = \left((-1+\theta_m)^3(13-10\theta_m+2\theta_m^2)(c^2+4ab\gamma)\right)/\left(2b^2(-240+494\theta_m-393\theta_m^2+151\theta_m^3-28\theta_m^4+2\theta_m^5)\gamma\right)$, $\partial I^{ARI}/\partial \theta_m > 0$

$$\frac{\partial Q_2^{ARI}}{\partial \theta_m} = \frac{c^2(-1+\theta_m)^3\left(19-12\theta_m+2\theta_m^2\right)+2b\left(2a(-1+\theta_m)^3\left(19-12\theta_m+2\theta_m^2\right)+bh\left(-205+417\theta_m-335\theta_m^2+133\theta_m^3-26\theta_m^4+2\theta_m^5\right)\right)\gamma}{4b(-1+\theta_m)^3\left(17-12\theta_m+2\theta_m^2\right)^2\gamma} > 0, \tag{B.75}$$

$$\frac{\partial q_2^{ARI}}{\partial \theta_m} = \frac{c^2(-1+\theta_m)^2\left(16-11\theta_m+2\theta_m^2\right)+b\left(4a(-1+\theta_m)^2\left(16-11\theta_m+2\theta_m^2\right)+bh\left(-35+42\theta_m-16\theta_m^2+2\theta_m^3\right)\right)\gamma}{2b(-1+\theta_m)^2\left(17-12\theta_m+2\theta_m^2\right)^2\gamma} > 0, \tag{B.76}$$

$$\frac{\partial p_2^{ARI}}{\partial \theta_m} = \frac{-c^2(-1+\theta_m)^2\left(16-11\theta_m+2\theta_m^2\right)+b\left(-4a(-1+\theta_m)^2\left(16-11\theta_m+2\theta_m^2\right)+bh\left(35-42\theta_m+16\theta_m^2-2\theta_m^3\right)\right)\gamma}{2b^2(-1+\theta_m)^2\left(17-12\theta_m+2\theta_m^2\right)^2\gamma} < 0. \tag{B.77}$$

(2) In scenario AAI,

$$\frac{\partial e^{AAI}}{\partial \theta_m} = 0, \tag{B.78}$$

$$\frac{\partial w_1^{AAI}}{\partial \theta_m} = -\frac{\left(c^2(-1+\theta_m)^2 \left(141 - 188(1+2\theta_r)\theta_m + \left(95+374\theta_r+377\theta_r^2\right)\theta_m^2 - 2\left(11+62\theta_r+125\theta_r^2+84\theta_r^3\right)\theta_m^3 + \left(2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4\right)\theta_m^4 \right) + 2b\left(-bh(-2+\theta_m+\theta_r\theta_m)^2 \left(95 - 4(37+58\theta_r)\theta_m + 3\left(29+90\theta_r+71\theta_r^2\right)\theta_m^2 - 2\left(11+54\theta_r+81\theta_r^2+44\theta_r^3\right)\theta_m^3 + \left(2+14\theta_r+33\theta_r^2+32\theta_r^3+14\theta_r^4\right)\theta_r^4 \right) + 2a(-1+\theta_m)^2 \left(141 - 188(1+2\theta_r)\theta_m + \left(95+374\theta_r+377\theta_r^2\right)\theta_m^2 - 2\left(11+62\theta_r+125\theta_r^2+84\theta_r^3\right)\theta_m^3 + \left(2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4\right)\theta_m^4 \right) \right)\gamma \right)}{\left(2b^2(-1+\theta_m)^2 \left(-34 + (41+61\theta_r)\theta_m - 2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2 + \left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3 \right)^2 \gamma \right)} < 0, \tag{B.79}$$

$$\frac{\partial w_2^{AAI}}{\partial \theta_m} = \frac{\left(-c^2(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right) + b\left(-4a(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right) + bh * \left(35 - 14(3+7\theta_r)\theta_m + 2\left(8+47\theta_r+50\theta_r^2\right)\theta_m^2 - 2\left(1+13\theta_r+34\theta_r^2+22\theta_r^3\right)\theta_m^3 + \theta_r\left(2+10\theta_r+16\theta_r^2+7\theta_r^3\right)\theta_m^4 \right) \right)\gamma \right)}{\left(b^2(-1+\theta_m)^2\left(17 - 2(6+11\theta_r)\theta_m + \left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma \right)} < 0. \tag{B.80}$$

Solving

$$\frac{\partial Q_1^{AAI}}{\partial \theta_m} = \frac{\left((-1+\theta_r)\left(-c^2(-1+\theta_m)^3 \left(193 - 4(70+123\theta_r)\theta_m + 6\left(26+88\theta_r+79\theta_r^2\right)\theta_m^2 - 4\left(10+48\theta_r+84\theta_r^2+51\theta_r^3\right)\theta_m^3 + \left(4+24\theta_r+60\theta_r^2+72\theta_r^3+33\theta_r^4\right)\theta_m^4 \right) + 2b\left(-2a(-1+\theta_m)^3 \left(193 - 4(70+123\theta_r)\theta_m + 6\left(26+88\theta_r+79\theta_r^2\right)\theta_m^2 - 4\left(10+48\theta_r+84\theta_r^2+51\theta_r^3\right)\theta_m^3 + \left(4+24\theta_r+60\theta_r^2+72\theta_r^3+33\theta_r^4\right)\theta_m^4 \right) + bh(-2+\theta_m+\theta_r\theta_m)^2 \left(-335 + 67(11+14\theta_r)\theta_m - 2\left(314+846\theta_r+515\theta_r^2\right)\theta_m^2 + 2\left(130+552\theta_r+717\theta_r^2+276\theta_r^3\right)\theta_m^3 - \left(52+312\theta_r+636\theta_r^2+532\theta_r^3+143\theta_r^4\right)\theta_m^4 + \left(4+32\theta_r+92\theta_r^2+120\theta_r^3+73\theta_r^4+14\theta_r^5\right)\theta_m^5 \right) \right)\gamma \right) \right)}{\left(4b(-1+\theta_m)^3\left(-34 + (41+61\theta_r)\theta_m - 2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2 + \left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3 \right)^2\gamma \right)} = 0, \tag{B.81}$$

reveals the threshold of h, when $0 < h < h_{mQ_1}^{AA}$, $\partial Q_1^{MAAI}/\partial \theta_m > 0$

$$h_{mQ_1}^{AA} = \begin{cases} {}^{AA}_{h}, 0 < \theta_m < 0.154,\ 0 < \theta_r < 1 \\ h_{rQ_1}^{AA}, 0.154 < \theta_m < 1, 0 < \theta_r < f_5(\theta_m), \\ {}^{AA}_{h}, 0.154 < \theta_m < 1, f_5(\theta_m) < \theta_r < 1 \end{cases} \tag{B.82}$$

$$\frac{\partial q_1^{AAI}}{\partial \theta_m} = \frac{((-1+\theta_r)(-c^2(-1+\theta_m)^2(141 - 188(1+2\theta_r)\theta_m + (95+374\theta_r+377\theta_r^2)\theta_m^2 - 2(11+62\theta_r+125\theta_r^2+84\theta_r^3)\theta_m^3 + (2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4)\theta_m^4) - 2b * (-bh(-2+\theta_m+\theta_r\theta_m)^2 95 - 4(37+58\theta_r)\theta_m + 3(29+90\theta_r+71\theta_r^2)\theta_m^2 - 2(11+54\theta_r+81\theta_r^2+44\theta_r^3)\theta_m^3 + (2+14\theta_r+33\theta_r^2+32\theta_r^3+14\theta_r^4)\theta_m^4) + 2a(-1+\theta_m)^2(141 - 188(1+2\theta_r)\theta_m + (95+374\theta_r+377\theta_r^2)\theta_m^2 - 2(11+62\theta_r+125\theta_r^2+84\theta_r^3)\theta_m^3 + (2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4)\theta_m^4)))}{4b(-1+\theta_m)^2(-34 + (41+61\theta_r)\theta_m - 2(8+25\theta_r+18\theta_r^2)\theta_m^2 + (2+10\theta_r+15\theta_r^2+7\theta_r^3)\theta_m^3)^2\gamma} > 0. \tag{B.83}$$

$$\frac{\partial p_1^{AAI}}{\partial \theta_m} = \frac{\left((-1+\theta_r)\left(c^2(-1+\theta_m)^2\begin{pmatrix}141-188(1+2\theta_r)\theta_m+\left(95+374\theta_r+377\theta_r^2\right)\theta_m^2- \\ 2\left(11+62\theta_r+125\theta_r^2+84\theta_r^3\right)\theta_m^3+\left(2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4\right)\theta_m^4\end{pmatrix}+2b*\left(-bh(-2+\theta_m+\theta_r\theta_m)^2\begin{pmatrix}95-4(37+58\theta_r)\theta_m+3\left(29+90\theta_r+71\theta_r^2\right)\theta_m^2- \\ 2\left(11+54\theta_r+81\theta_r^2+44\theta_r^3\right)\theta_m^3+\left(2+14\theta_r+33\theta_r^2+32\theta_r^3+14\theta_r^4\right)\theta_m^4\end{pmatrix}+2a(-1+\theta_m)^2\begin{pmatrix}141-188(1+2\theta_r)\theta_m+\left(95+374\theta_r+377\theta_r^2\right)\theta_m^2-2\left(11+62\theta_r+125\theta_r^2+84\theta_r^3\right)\theta_m^3+ \\ \left(2+14\theta_r+41\theta_r^2+56\theta_r^3+28\theta_r^4\right)\theta_m^4\end{pmatrix}\right)\gamma\right)\right)}{\left(4b^2(-1+\theta_m)^2\left(\theta_m-2\left(8+25\theta_r+18\theta_r^2\right)\theta_m^2+\left(2+10\theta_r+15\theta_r^2+7\theta_r^3\right)\theta_m^3\right)^2\gamma\right)} < 0. \tag{B.84}$$

Solving

$$\frac{\partial I^{AAI}}{\partial \theta_m} = \frac{\left((-1+\theta_r)\left(-c^2(-1+\theta_m)^3\left(13-2(5+8\theta_r)\theta_m+\left(2+6\theta_r+5\theta_r^2\right)\theta_m^2\right)+2b\left(-2a(-1+\theta_m)^3\left(13-2(5+8\theta_r)\theta_m+\left(2+6\theta_r+5\theta_r^2\right)\theta_m^2\right)+bh\begin{pmatrix}-240+(494+706\theta_r)\theta_m-\left(393+1190\theta_r+817\theta_r^2\right)\theta_m^2+\left(151+726\theta_r+1059\theta_r^2+464\theta_r^3\right)\theta_m^3- \\ \left(28+190\theta_r+441\theta_r^2+412\theta_r^3+129\theta_r^4\right)\theta_m^4+\left(2+18\theta_r+59\theta_r^2+88\theta_r^3+59\theta_r^4+14\theta_r^5\right)\theta_m^5\end{pmatrix}\right)\gamma\right)\right)}{\left(4b(-1+\theta_m)^3\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^3\right)^2\gamma\right)} = 0, \tag{B.85}$$

reveals the threshold of h, when $0 < h < h_{mI}^{AA}$, $\partial I^{AAI}/\partial \theta_m > 0$.

$$\begin{aligned} h_{mI}^{AA} = {} & \left(\left(-1+\theta_m\right)^3\left(13-2(5+8\theta_r)\theta_m+\left(2+6\theta_r+5\theta_r^2\right)\theta_m^2\right)\left(c^2+4ab\gamma\right)\right)/\left(2b^2\left(-240+(494+706\theta_r)\theta_m\right.\right. \\ & -\left(393+1190\theta_r+817\theta_r^2\right)\theta_m^2+\left(151+726\theta_r+1059\theta_r^2+464\theta_r^3\right)* \\ & \left.\left.\cdot\,\theta_m^3-\left(28+190\theta_r+441\theta_r^2+412\theta_r^3+129\theta_r^4\right)\theta_m^4+\left(2+18\theta_r+59\theta_r^2+88\theta_r^3+59\theta_r^4+14\theta_r^5\right)\theta_m^5\right)\gamma\right), \end{aligned} \tag{B.86}$$

$$\frac{\partial Q_2^{AAI}}{\partial \theta_m} = -\frac{\left((-1+\theta_r)\left(c^2(-1+\theta_m)^3\right)\left(19-2(6+13\theta_r)\theta_m+\left(2+8\theta_r+9\theta_r^2\right)\theta_m^2\right)+2b\left(2a(-1+\theta_m)^3\left(19-2(6+13\theta_r)\theta_m+\left(2+8\theta_r+9\theta_r^2\right)\theta_m^2\right)+bh\left(-205+(417+608\theta_r)\theta_m-\left(335+998\theta_r+717\theta_r^2\right)\theta_m^2+\left(133+606\theta_r+891\theta_r^2+420\theta_r^3\right)\theta_m^3-\left(26+162\theta_r+363\theta_r^2+352\theta_r^3+122\theta_r^4\right)\theta_m^4+\left(2+16\theta_r+49\theta_r^2+72\theta_r^3+52\theta_r^4+14\theta_r^5\right)\theta_m^5\right)\right)\gamma\right)}{4b(-1+\theta_m)^3\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma} > 0, \tag{B.87}$$

$$\frac{\partial q_2^{AAI}}{\partial \theta_m} = \frac{\left((-1+\theta_r)\left(-c^2(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)+b\left(-4a(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)+bh\left(35-14(3+7\theta_r)\theta_m+2\left(8+47\theta_r+50\theta_r^2\right)\theta_m^2-22\left(1+13\theta_r+34\theta_r^2+22\theta_r^3\right)\theta_m^3+\theta_r\left(2+10\theta_r+16\theta_r^2+7\theta_r^3\right)\theta_m^4\right)\right)\gamma\right)\right)}{2b(-1+\theta_m)^2\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2\right)^2\gamma} > 0. \tag{B.88}$$

$$\frac{\partial p_2^{AAI}}{\partial \theta_m} = \frac{\left((-1+\theta_r)\left(c^2(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)+b\left(4a(-1+\theta_m)^2\left(16-(11+21\theta_r)\theta_m+\left(2+7\theta_r+7\theta_r^2\right)\theta_m^2\right)-bh\begin{pmatrix}35-14(3+7\theta_r)\theta_m+2\left(8+47\theta_r+50\theta_r^2\right)\theta_m^2- \\ 2\left(1+13\theta_r+34\theta_r^2+22\theta_r^3\right)\theta_m^2+\theta_r\left(2+10\theta_r+16\theta_r^2+7\theta_r^3\right)\theta_m^4\end{pmatrix}\right)\gamma\right)\right)}{\left(2b^2(-1+\theta_m)^2\left(17-2(6+11\theta_r)\theta_m+\left(2+8\theta_r+7\theta_r^2\right)\theta_m^2 s\right)^2\gamma\right)} < 0. \tag{B.89}$$

(3) In scenario ARN,

$$\begin{aligned}
&\frac{\partial e^{ARN}}{\partial \theta_m} = 0,\\
&\frac{\partial w_1^{ARN}}{\partial \theta_m} = \frac{\partial w_2^{ARN}}{\partial \theta_m} = -\frac{c^2 + 4ab\gamma}{4b^2(-2+\theta_m)^2\gamma} < 0,\\
&\frac{\partial Q_1^{ARN}}{\partial \theta_m} = \frac{\partial Q_2^{ARN}}{\partial \theta_m} = \frac{\partial q_1^{ARN}}{\partial \theta_m} = \frac{\partial q_2^{ARN}}{\partial \theta_m} = \frac{c^2 + 4ab\gamma}{8b(-2+\theta_m)^2\gamma} > 0,\\
&\frac{\partial p_1^{ARN}}{\partial \theta_m} = \frac{\partial p_2^{ARN}}{\partial \theta_m} = -\frac{c^2 + 4ab\gamma}{8b^2(-2+\theta_m)^2\gamma} < 0.
\end{aligned} \tag{B.90}$$

(4) In scenario AAN,

$$\begin{aligned}
&\frac{\partial e^{AAN}}{\partial \theta_m} = 0, \frac{\partial w_1^{AAN}}{\partial \theta_m} = \frac{\partial w_2^{AAN}}{\partial \theta_m} = -\frac{c^2 + 4ab\gamma}{4b^2(-2+\theta_m+\theta_r\theta_m)^2\gamma} < 0, \frac{\partial Q_1^{AAN}}{\partial \theta_m} = \frac{\partial Q_2^{AAN}}{\partial \theta_m}\\
&= \frac{\partial q_1^{AAN}}{\partial \theta_m} = \frac{\partial q_2^{AAN}}{\partial \theta_m} = -\frac{(-1+\theta_r)(c^2 + 4ab\gamma)}{8b(-2+\theta_m+\theta_r\theta_m)^2\gamma} > 0,\\
&\frac{\partial p_1^{AAN}}{\partial \theta_m} = \frac{\partial p_2^{AAN}}{\partial \theta_m} = \frac{(-1+\theta_r)(c^2 + 4ab\gamma)}{8b^2(-2+\theta_m+\theta_r\theta_m)^2\gamma} < 0.
\end{aligned} \tag{B.91}$$

□

Proof of Proposition 8.

To explore the impact of manufacturer's altruistic preference, we compare profits under four different scenarios (ARI, AAI, ARN, and AAN):

(1) In scenario ARI,

$$\frac{\partial \Pi_r^{ARI}}{\partial \theta_m} = -\frac{c^4(-1+\theta_m)^4(2445 - 5306\theta_m + 4818\theta_m^2 - 2346\theta_m^3 + 647\theta_m^4 - 96\theta_m^5 + 6\theta_m^6) + 4bc^2(-1+\theta_m)^2(-bh(-2+\theta_m)^3(-371 + 661\theta_m - 458\theta_m^2 + 159\theta_m^3 - 28\theta_m^4 + 2\theta_m^5) + 2a(-1+\theta_m)^2(2445 - 5306\theta_m + 4818\theta_m^2 - 2346\theta_m^3 + 647\theta_m^4 - 96\theta_m^5 + 6\theta_m^6))\gamma + 4b^2 * (-4abh(-2+\theta_m)^3(-1+\theta_m)^2(-371 + 661\theta_m - 458\theta_m^2 + 159\theta_m^3 - 28\theta_m^4 + 2\theta_m^5) + b^2h^2(-2+\theta_m)^4(1280 - 3432\theta_m + 3698\theta_m^2 - 2054\theta_m^3 + 619\theta_m^4 - 96\theta_m^5 + 6\theta_m^6) + 4a^2(-1+\theta_m)^4(2445 - 5306\theta_m + 4818\theta_m^2 - 2346\theta_m^3 + 647\theta_m^4 - 96\theta_m^5 + 6\theta_m^6))\gamma^2}{8b^3(-1+\theta_m)^4(-34 + 41\theta_m - 16\theta_m^2 + 2\theta_m^3)^3\gamma^2} > 0, \tag{B.92}$$

$$\frac{\partial \Pi_m^{ARI}}{\partial \theta_m} = \frac{\left(\begin{array}{c} c^4(-1+\theta_m)^4(408 + 1205\theta_m - 3804\theta_m{}^2 + 3882\theta_m{}^3 - 2028\theta_m{}^4 + 591\theta_m{}^5 - 92\theta_m{}^6 + 6\theta_m{}^7) + \\ 4bc^2(-1+\theta_m)^2 * \\ \left(\begin{array}{c} -bh(-2+\theta_m)^3(-119 - 134\theta_m + 505\theta_m{}^2 - 416\theta_m{}^3 + 155\theta_m{}^4 - 28\theta_m{}^5 + 2\theta_m{}^6) + \\ 2a(-1+\theta_m)^2(408 + 1205\theta_m - 3804\theta_m{}^2 + 3882\theta_m{}^3 - 2028\theta_m{}^4 + 591\theta_m{}^5 - 92\theta_m{}^6 + 6\theta_m^7) \end{array}\right)\gamma + \\ 4b^2\left(\begin{array}{c} -4abh(-2+\theta_m)^3(-1+\theta_m)^2(-119 - 134\theta_m + 505\theta_m^2 - 416\theta_m^3 + 155\theta_m^4 - 28\theta_m^5 + 2\theta_m^6) + \\ b^2h^2(-2+\theta_m)^4(-680 + 3290\theta_m - 5748\theta_m^2 + 5034\theta_m^3 - 2464\theta_m^4 + 683\theta_m^5 - 100\theta_m^6 + 6\theta_m^7) + \\ 4a^2(-1+\theta_m)^4(408 + 1205\theta_m - 3804\theta_m^2 + 3882\theta_m^3 - 2028\theta_m^4 + 591\theta_m^5 - 92\theta_m^6 + 6\theta_m^7) \end{array}\right)\gamma^2 \end{array}\right)}{\left(8b^3(-2+\theta_m)^3(-1+\theta_m)^4(17 - 12\theta_m + 2\theta_m^2)^3\gamma^2\right)} < 0, \tag{B.93}$$

$$\frac{\partial \Pi^{ARI}}{\partial \theta_m} = \frac{c^4(-1+\theta_m)^4(2037 - 4474\theta_m + 4148\theta_m^2 - 2080\theta_m^3 + 595\theta_m^4 - 92\theta_m^5 + 6\theta_m^6) + 4bc^2(-3+\theta_m)(-1+\theta_m)^3 * (-bh(-2+\theta_m)^3(-84 + 69\theta_m - 20\theta_m^2 + 2\theta_m^3) + 2a(679 - 1944\theta_m + 2226\theta_m^2 - 1334\theta_m^3 + 447\theta_m^4 - 80\theta_m^5 + 6\theta_m^6))\gamma + 4b^2(-4abh(2 - 3\theta_m + \theta_m^2)^3(252 - 291\theta_m + 129\theta_m^2 - 26\theta_m^3 + 2\theta_m^4) + b^2h^2(-2+\theta_m)^4(1960 - 4762\theta_m + 4684\theta_m^2 - 2404\theta_m^3 + 679\theta_m^4 - 100\theta_m^5 + 6\theta_m^6) + 4a^2(-1+\theta_m)^4(2037 - 4474\theta_m + 4148\theta_m^2 - 2080\theta_m^3 + 595\theta_m^4 - 92\theta_m^5 + 6\theta_m^6))\gamma^2}{8b^3(-2+\theta_m)^3(-17 + 29\theta_m - 14\theta_m^2 + 2\theta_m^3)^3\gamma^2} > 0. \tag{B.94}$$

(2) In scenario AAI,

$$\frac{\partial \Pi_r^{AAI}}{\partial \theta_m}=\frac{\left(\begin{array}{c} c^4(-1+\theta_m)^4C_{12}+4bc^2(-1+\theta_m)^2\left(-bh(-2+\theta_m+\theta_r\theta_m)^3C_{13}+2a(-1+\theta_m)^2C_{12}\right)\gamma- \\ 4b^2\left(\begin{array}{c} 4abh(-1+\theta_m)^2(-2+\theta_m+\theta_r\theta_m)^3C_{13}-4a^2(-1+\theta_m)^4C_{12}+ \\ b^2h^2(-2+\theta_m+\theta_r\theta_m)^4\left(\begin{array}{c} 1280-3432\theta_m+36989\theta_m{}^2-2054\theta_m{}^3+619\theta_m{}^4-96\theta_m{}^5+6\theta_m{}^6+ \\ 21\theta_r{}^7\theta_m{}^6(-3+2\theta_m)+\theta_r{}^6\theta_m{}^5\left(732-773\theta_m+188\theta_m{}^2\right)+ \\ \theta_r{}^5\theta_m{}^4\left(-3351+4576\theta_m-1922\theta_m{}^2+256\theta_m{}^3\right)+ \\ \theta_r{}^4\theta_m{}^3\left(7912-12701\theta_m+70036\theta_m{}^2-1662\theta_m{}^3+150\theta_m{}^4\right)+ \\ \theta_r{}^3\theta_m{}^2\left(-10274+178788\theta_m-110500\theta_m{}^2+3132\theta_m{}^3-461\theta_m{}^4+40\theta_m{}^5\right)+ \\ \theta_r{}^2\theta_m\left(6998-11454\theta_m+5304\theta_m{}^2+26\theta_m{}^3-502\theta_m{}^4+65\theta_m{}^5+4\theta_m{}^6\right)+ \\ \theta_r\left(-1960+1194\theta_m+3750\theta_m{}^2-5240\theta_m{}^3+2657\theta_m{}^4-598\theta_m{}^5+50\theta_m{}^6\right) \end{array}\right) \end{array}\right)\gamma^2 \end{array}\right)}{\left(8b^3(-1+\theta_m)^4\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r{}^2\right)\theta_m{}^2+\left(2+10\theta_r+15\theta_r{}^2+7\theta_r{}^3\right)\theta_m{}^3\right)^3\gamma^2\right)}>0 \tag{B.95}$$

$$\frac{\partial \Pi_m^{AAI}}{\partial \theta_m}=-\frac{\left(\begin{array}{c} c^4(-1+\theta_m)^4C_{14}+4bc^2(-1+\theta_m)^2\left(-bh(-2+\theta_m+\theta_r\theta_m)^3C_{15}+2a(-1+\theta_m)^2C_{14}\right)\gamma+ \\ 4b^2\left(\begin{array}{c} -4abh(-1+\theta_m)^2(-2+\theta_m+\theta_r\theta_m)^3C_{15}+b^2h^2(-2+\theta_m+\theta_r\theta_m)^4 * \\ \left(\begin{array}{c} 680-70(47+21\theta_r)\theta_m+12\left(479+687\theta_r+24\theta_r{}^2\right)\theta_m{}^2+ \\ 2\left(-2517-6819\theta_r-3486\theta_r{}^2+922\theta_r{}^3\right)\theta_m{}^3- \\ 8\left(-308-1285\theta_r-1482\theta_r{}^2-174\theta_r{}^3+274\theta_r{}^4\right)\theta_m{}^4+ \\ \left(-683-3977\theta_r-7466\theta_r{}^2-4390\theta_r{}^3+11510\theta_r{}^4+1085\theta_r{}^5\right)\theta_m{}^5+ \\ \left(100+766\theta_r+2062\theta_r{}^2+2228\theta_r{}^3+524\theta_r{}^4-670\theta_r{}^5-250\theta_r{}^6\right)\theta_m{}^6+ \\ \left(-6-58\theta_r-209\theta_r{}^2-339\theta_r{}^3-218\theta_r{}^4+26\theta_r{}^5+103\theta_r{}^6+21\theta_r{}^7\right)\theta_m{}^7 \end{array}\right)+ \\ 4a^2(-1+\theta_m)^4C_{14} \end{array}\right)\gamma^2 \end{array}\right)}{\left(8b^3(-1+\theta_m)^4\left(-34+(41+61\theta_r)\theta_m-2\left(8+2\theta_r+18\theta_r{}^2\right)\theta_m{}^2+\left(2+10\theta_r+15\theta_r{}^2+7\theta_r{}^3\right)\theta_m{}^3\right)^3\gamma^2\right)}<0$$

$$\frac{\partial \Pi^{AAI}}{\partial \theta_m}=-\frac{\left(\begin{array}{c} (-1+\theta_r)\left(c^4(-1+\theta_m)^4C_{11}+4bc^2(-1+\theta_m)^3(-3+\theta_m+2\theta_r\theta_m) * \right. \\ \left(\begin{array}{c} -bh(-2+\theta_m+\theta_r\theta_m)^3 * \\ \left(-84+3(23+61\theta_r)\theta_m-2\left(10+49\theta_r+67\theta_r{}^2\right)\theta_m{}^2+\left(2+14\theta_r+35\theta_r{}^2+33\theta_r{}^3\right)\theta_m{}^3\right)+ \\ 2a(-1+\theta_m)\left(\begin{array}{c} -679+5(253+426\theta_r)\theta_m-\left(961+3138\theta_r+2691\theta_r{}^2\right)\theta_m{}^2+\left(373+1764\theta_r+2943\theta_r{}^2+1710\theta_r{}^3\right)\theta_m{}^3- \\ \left(74+450\theta_r+1089\theta_r{}^2+1236\theta_r{}^3+546\theta_r{}^4\right)\theta_m{}^4+\left(6+44\theta_r+137\theta_r{}^2+226\theta_r{}^3+196\theta_r{}^4+70\theta_r{}^5\right)\theta_m{}^5 \end{array}\right) \end{array}\right)\gamma+ \\ 4b^2\left(\begin{array}{c} -4abh(-1+\theta_m)^3(-2+\theta_m+\theta_r\theta_m)^3\left(\begin{array}{c} 252-3(97+239\theta_r)\theta_m+3\left(43+205\theta_r+256\theta_r{}^2\right)\theta_m{}^2- \\ \left(26+180\theta_r+435\theta_r{}^2+367\theta_r{}^3\right)\theta_m{}^3+ \\ \left(2+18\theta_r+63\theta_r{}^2+103\theta_r{}^3+66\theta_r{}^4\right)\theta_m{}^4 \end{array}\right)+ \\ b^2h^2(-2+\theta_m+\theta_r\theta_m)^4\left(\begin{array}{c} 1960-2(2381+3499\theta_r)\theta_m+2\left(2342+7221\theta_r+5137\theta_r{}^2\right)\theta_m{}^2- \\ 4\left(601+2881\theta_r+4340\theta_r{}^2+1978\theta_r{}^3\right)\theta_m{}^3+ \\ \left(679+4496\theta_r+10542\theta_r{}^2+10332\theta_r{}^3+3351\theta_r{}^4\right)\theta_m{}^4- \\ 2\left(50+429\theta_r+1390\theta_r{}^2+2124\theta_r{}^3+1521\theta_r{}^4+366\theta_r{}^5\right)\theta_m{}^5+ \\ \left(6+64\theta_r+269\theta_r{}^2+568\theta_r{}^3+636\theta_r{}^4+354\theta_r{}^5+63\theta_r{}^6\right)\theta_m{}^6 \end{array}\right)+4a^2(-1+\theta_m)^4C_{11} \end{array}\right)\gamma^2 \end{array}\right)}{\left(8b^3(-1+\theta_m)^3\left(-34+(41+61\theta_r)\theta_m-2\left(8+25\theta_r+18\theta_r{}^2\right)\theta_m{}^2+\left(2+10\theta_r+15\theta_r{}^2+7\theta_r{}^3\right)\theta_m{}^3\right)^3\gamma^2\right)}>0 \tag{B.96}$$

$$C_{12}=\begin{pmatrix} -2445+5306\theta_m-48180_m{}^2+2346\theta_m{}^3-647\theta_m{}^4+96\theta_m{}^5-6\theta_m{}^6+28\theta_r{}^7\theta_m{}^6(5+\theta_m)+6\theta_r{}^6\theta_m{}^5\left(-217+4\theta_m+17\theta_m{}^2\right)+ \\ 6\theta_r{}^5\theta_m{}^4\left(843-160\theta_m-119\theta_m{}^2+24\theta_m{}^3\right)+2\theta_r{}^4\theta_m{}^3\left(-5256+14590_m+1389\theta_m{}^2-581\theta_m{}^3+49\theta_m{}^4\right)+ \\ \theta_r{}^3\theta_m{}^2\left(12333-2400\theta_m-7790\theta_m{}^2+4500\theta_m{}^3-795\theta_m{}^4+32\theta_m{}^5\right)+\theta_r\left(2037+5298\theta_m-13578\theta_m{}^2+10824\theta_m{}^3-4121\theta_m{}^4+774\theta_m{}^5-58\theta_m{}^6\right)+ \\ \theta_r{}^2\theta_m\left(-7748-2505\theta_m+14022\theta_m{}^2-9698\theta_m{}^3+2682\theta_m{}^4-285\theta_m{}^5+4\theta_m{}^6\right) \end{pmatrix} \tag{B.97}$$

$$C_{13}=\begin{pmatrix} 371-661\theta_m+458\theta_m{}^2-159\theta_m{}^3+28\theta_m{}^4-2\theta_m{}^5+35\theta_r{}^6\theta_m{}^6+ \\ 6\theta_r{}^5\theta_m{}^4\left(-11-33\theta_m+9\theta_m{}^2\right)+\theta_r{}^4\theta_m{}^3\left(367+417\theta_m-285\theta_m{}^2+26\theta_m{}^3\right)+ \\ 3\theta_r{}^2\theta_m\left(239+223\theta_m-432\theta_m{}^2+164\theta_m{}^3-19\theta_m{}^4\right)+4\theta_r{}^3\theta_m{}^2\left(-192-128\theta_m+183\theta_m{}^2-39\theta_m{}^3+\theta_m{}^4\right)- \\ 2\theta_r\left(126+385\theta_m-713\theta_m{}^2+390\theta_m{}^3-91\theta_m{}^4+8\theta_m{}^5\right) \end{pmatrix} \tag{B.98}$$

$$C_{14}=\begin{pmatrix} -408+(-1205+4061\theta_r)\theta_m-6\left(-634+63\theta_r+1999\theta_r{}^2\right)\theta_m{}^2+3\left(-1294-2458\theta_r+2773\theta_r{}^2+5739\theta_r{}^3\right)\theta_m{}^3- \\ 4\left(-507-1854\theta_r-906\theta_r{}^2+3377\theta_r{}^3+3460\theta_r{}^4\right)\theta_m{}^4+3\left(-197-1043\theta_r-1622\theta_r{}^2+414\theta_r{}^3+3170\theta_r{}^4+2134\theta_r{}^5\right)\theta_m{}^5- \\ 2\left(-46-315\theta_r-777\theta_r{}^2-586\theta_r{}^3+750\theta_r{}^4+1602\theta_r{}^5+800\theta_r{}^6\right)\theta_m{}^6+\left(-6-50\theta_r-165\theta_r{}^2-243\theta_r{}^3-50\theta_r{}^4+330\theta_r{}^5+424\theta_r{}^6+168\theta_r{}^7\right)\theta_m{}^7 \end{pmatrix} \tag{B.99}$$

$$C_{15}=\begin{pmatrix} 119+(134-848\theta_r)\theta_m+5\left(-101+68\theta_r+390\theta_r{}^2\right)\theta_m{}^2-4\left(-104-193\theta_r+363\theta_r{}^2+529\theta_r{}^3\right)\theta_m{}^3+ \\ \left(-155-628\theta_r-216\theta_r{}^2+1596\theta_r{}^3+1188\theta_r{}^4\right)\theta_m{}^4-2\left(-14-85\theta_r-144\theta_r{}^2+72\theta_r{}^3+363\theta_r{}^4+165\theta_r{}^5\right)\theta_m{}^5+ \\ \left(-2-16\theta_r-45\theta_r{}^2-36\theta_r{}^3+63\theta_r{}^4+120\theta_r{}^5+35\theta_r{}^6\right)\theta_m{}^6 \end{pmatrix} \tag{B.100}$$

(3) In scenario ARN,

$$\begin{aligned} \frac{\partial \prod_r^{ARN}}{\partial \theta_m} &= -\frac{\left(c^2+4ab\gamma\right)^2}{16b^3(-2+\theta_m)^3\gamma^2}>0, \\ \frac{\partial \prod_m^{ARN}}{\partial \theta_m} &= \frac{\theta_m\left(c^2+4ab\gamma\right)^2}{16b^3(-2+\theta_m)^3\gamma^2}<0, \\ \frac{\partial \prod^{ARN}}{\partial \theta_m} &= \frac{(-1+\theta_m)\left(c^2+4ab\gamma\right)^2}{16b^3(-2+\theta_m)^3\gamma^2}>0. \end{aligned} \tag{B.101}$$

(4) In scenario AAN,

$$\begin{aligned} \frac{\partial \prod_r^{AAN}}{\partial \theta_m} &= \frac{(-1+\theta_r)\left(c^2+4ab\gamma\right)^2}{16b^3(-2+\theta_m+\theta_r\theta_m)^3\gamma^2}>0, \\ \frac{\partial \prod_m^{AAN}}{\partial \theta_m} &= -\frac{(-1+\theta_r)\theta_m\left(c^2+4ab\gamma\right)^2}{16b^3(-2+\theta_m+\theta_r\theta_m)^3\gamma^2}<0, \\ \frac{\partial \prod^{AAN}}{\partial \theta_m} &= -\frac{(-1+\theta_r)(-1+\theta_m)\left(c^2+4ab\gamma\right)^2}{16b^3(-2+\theta_m+\theta_r\theta_m)^3\gamma^2}>0. \end{aligned} \tag{B.102}$$

□

Data Availability

No additional data sets are used in this article.

Conflicts of Interest

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

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