Food Manufacturers' Sustainable Product Launch Strategy: Game Theory Approach

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Introduction

There are four key reasons why food manufacturers are interested in sustainable strategies, investing in sustainable practices, and/or launching a new sustainable product to the market. First, launching new sustainable products can be a public relations strategy of the firms to improve their image and brand. There were 13,000 new sustainable food and beverages launched between 2005-10 (Mintel, 2010). Consumers are more likely to percept which brands are green when brands are familiar and have good reputations in general, especially if brands have green marketing campagins (Mintel, 2010). This is also supported by the Accenture and United Nation Global Compact (UNGC) who interviewed 766 CEOs around the world in 2010 and found that manufacturers invest in sustainability for three reasons: brand, trust and reputation (Broder, 2010). Second, manufacturers also invest in sustainable practices to reduce production costs and increase their competitiveness. The Accenture and UNGC studies showed that CEOs realize that sustainablility practice can be a source of cost efficiency and revenue growth even during the economic downturn period (Broder, 2010). Third, global retailers are using their market power to strongly encourage manufactures to produce sustainable products. For example, Walmart, which has more than 100,000 global suppliers and more than 8,000 stores, is currently creating a "Sustainability Index" (targeting 2014 completion) that can measure the environmental performance of suppliers in order to inform its customers about a product's "lifecycle", and create efficiecy by reducing costs and waste (Mintel, 2010). With WalMart's market power, its sustainablility practice is expected to influence not only other retailers but also manufactures in the near future. Lastly, Consumers are demanding manufacturers to be more environmentally friendly (Oberholtzer, Greene, and Lopez, 2006) and want to know where their food comes from and how it is produced. 84% of the U.S. interviewed consumers indicate that they sometimes or regularly purchase sustainable food and drink, expecially local and recyclable packaging claims (Mintel, 2010).

Although sustainability is at the forefront of most food manufacturer and retailing CEOs' minds, most food manufactures are reluctant to implement sustainable practices, and develop and market new sustainable food products. Part of their reluctance is due to two main reasons:1) lack of technology to produce sustainable products, and 2) lack of systematic decision model that includes all variables especially the variables from the demand side.

The model that will be developed in this paper is a culmination of product launch strategies, and agribusiness and game theory literature. Several works studied both theoretically and empirically the ***innovation strategies*** of firms in oligopoly markets, especially the theoretical and empirical literature on innovation strategy; on launch strategies, food industry and game theory, specifically ***duopoly markets*** for innovation strategies (Yoon, and Lilien, 1985, Acs, and Audretsch, 1987, Dockner, and Jorgensen, 1988, Debruyne, et. al., 2002, Broring, 2007). Moreover, numerous industrial organization papers investigate ***new product launching strategies***, such as the ***signaling game*** (Robertson, Eliashberg, and Rymon, 1995), and reaction strategies (Debruyne, et al., 2002). In the ***agribusiness*** field, several papers used ***game theory*** to construct agriculture product launch strategies (Russo, Cardillo, and Perito, 2003, Hitsch, 2006, and Broring, 2007).

The Egg Industry

The egg industry in the U.S. is a huge and important industry with a market size equal to $ 5.10 billion in 2007 and a growth rate from 2006 to 2007 equal to 11.8% (Mintel, 2008). There are two main segmentations for the egg market which are fresh eggs, and egg substitutes. In 2007, egg substitutes had a market share of only 5.2%; while, fresh eggs had a market share equal to 94.8% which has a market size equal to $ 4.89 billion (Mintel, 2008). Fresh egg categories are regular eggs and specialty eggs. Examples of specialty eggs are free-range eggs, organic eggs, eggs fortified with Omega-3, low-cholesterol eggs, and vegetarian-fed eggs.

Store brands dominate national brands and regional brands in the egg market. That is in 2007 store brands had a market share equal to 68.8%, while Eggland's Best, Rose Acre Farms, Land O'Lakes Inc, Cal Maine Foods, Dean Food Co., Michael Foods Inc., ConAgra Foods, Inc., and others had market share equal to 7.9%, 2%, 1.4%, 1.2%, 1.1%, 0.9%, 0.9%, and 15.8%, respectively (Mintel, 2008).

In our study, sustainable eggs include free-range eggs, and free-cage eggs. Hens are generally raised in a cage system. There are about **95%** of eggs in the U.S. (and 90% around the world) from cage (conventional) housing systems (United Egg Producer, ---). There is no legal definition for free-range and free-cage eggs in the U.S. However, according to the Egg Nutrition Center, free-range eggs are from hens that are either raised outdoors or can access outside; while, free-cage eggs are from hens that live in indoor floor facilities, but do not necessarily have access to the outdoors. Consumers who have concerns on animal welfare prefer and have more willingness to pay for a method of animal husbandry that allows hens to roam freely instead of being in cages (Bennett, 1998).

The free-range or free-cage egg is not a new product in the sense that it is never launched in the U.S. market before. However, the food manufactures have to decide whether they should launch the sustainable egg in the new region/market that there is no supply of the sustainable eggs before or there is no information about the demand side. There are two main reasons why the egg industry is a great industry to use as an example to understand the egg manufactures' decision making whether the firms should launch the sustainable egg which is a free-rang or free-cage egg. First, an increase in concern about the welfare of animals, and the new legislation concerning egg production influence many egg manufactures making the decision to market sustainable eggs; which include cage-free and free-range eggs. Second, the data about the costs and the price premiums of the sustainable eggs for the simulation part are available.

This study is unique for four main reasons. First, our study captures concern about the difference between consumers' maximum willingness to pay for the sustainable and the conventional products which is a constant term in an inverse demand. Second, the model captures the degrees of substitution between products which include both the degrees of substitution between different types of products (conventional and sustainable products), and the degrees of substitution between brands of products. Third, the model is extended to incorporate demand uncertainty (Appendix A). That is a firm does not know whether consumers are willing to pay a premium for a new sustainable food products. The last reason is that the study incorporates these dimensions within a food supply chain context. Specifically, we simulate a new sustainable product launch in the egg industry.

Objectives

The Objectives of the study are: 1) to model the manufacturers decision making process for launching a sustainable product, and 2) to construct a model that informs the food manufacturers that under which conditions make the leader firm's profit higher than the follower firm's profit. Specifically, we explore the optimal conditions for a food manufacturer to invest in launching a new sustainable food product; which includes:1) threshold for consumers' maximum willingness to pay 2) degrees of substitution between products, and 3) critical value of marginal costs.

Model

In this analysis, a frim produces only one type of product, either a conventional product or a sustainable product in each stage for the simplicity of the model. There are three stages in the analysis as shown in Fiugure 1. **The first stage** is a status quo stage which both leader (firm i) and follower (firm j) produce a conventional product (c). Both firms set prices as a strategy simultaneously. This stage will continue as a repeated game until the leader decides to launch a new sustainable product. **The second stage** happens when the leader firm has know-how to produce a sustainable product (s) and decides to launch it to get a higher profit. In this stage, both firms use price as the choice variable and set their prices simultaneously. This stage is concluded when the follower also decides to launch a new sustainable product. In **the third stage**, both leader and follower firms launch a new sustainable product. The leader sets the price of its own sustainable product first and the follower sets the price of its product later since the leader has already produced sustainable product. This stage is concluded when the market becomes similar to the first stage, except both firms produce the sustainable products at this time. This can be explained as a cycle or loop of product launching.

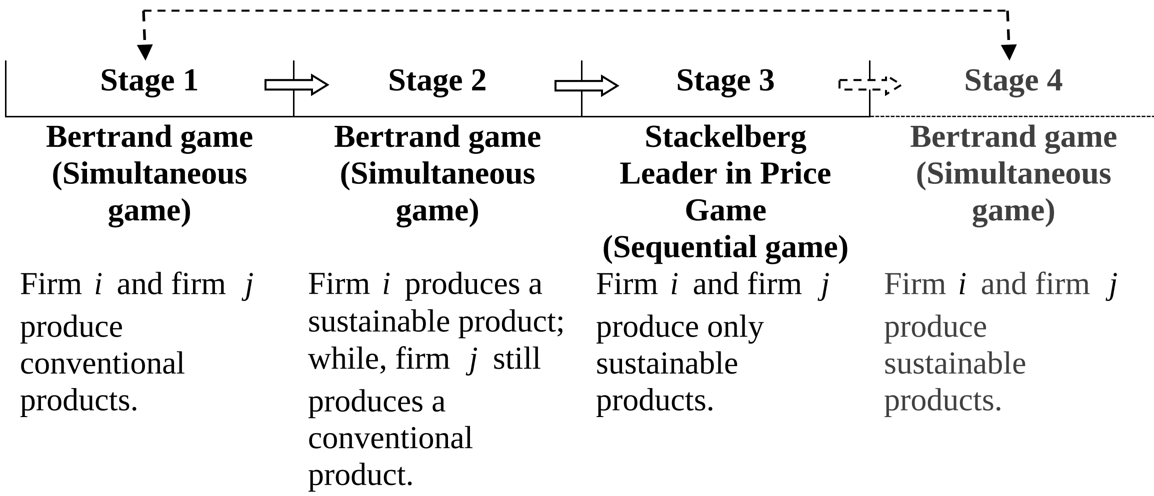


Figure 1: Stages and types of game[1]

This study uses a vertical differentiated products model[2] because branded products are similar but they are not identical/ homogeneous. The structure of inverse demand functions for the vertical differentiated products of firm i in the first stage is $p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j}$. $p_{c,i}$ is the price of the conventional product of firm i. a_c represents the consumers' maximum willingness to pay for a conventional product which has a value greater than zero. $q_{c,i}$ is the quantity demand for conventional products of firm i, which we normalize the coefficient to one for the simplicity. The negative sign for $q_{c,i}$ shows an inverse relationship between price and quantity (law of demand). $q_{c,j}$ is the quantity of conventional products of firm j or a quantity of a substitution good. The negative sign for $q_{c,j}$ shows a negative relationship between price and quantity of its substitute good. γ_1 is the degree of substitution between the conventional products of firm i and firm j in the first stage. γ_1 has a value between zero and one. If γ_1 is equal to zero, firm i is a monopoly, that is, the quantity of the same product from firm j has no effect on the price of the conventional good from firm i. On the other hand, if γ_1 equals one, $q_{c,j}$ is a perfect substitute product of $q_{c,i}$. This means that the higher value of γ, the higher value of the degree of substitution. The structure of the inverse demand functions of firm i and j in every stage are similar to the above inverse demand function except the degree of substitution in the second stage is asymmetrical.

The inverse demand functions in each stage are as follows:

Stage 1: A Bertrand game

$$p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j}\text{, and} \quad (1)$$

$$p_{c,j} = a_c - q_{c,j} - \gamma_1 q_{c,i}. \quad (2)$$

Stage 2: A Bertrand game

[1] Assume that firm i is a leader in our study.
[2] The verticle differentiated products are defined as the products are different in quality.

$$p_{s,i} = a_s - q_{s,i} - \gamma_2^s q_{c,j} \text{, and} \quad (3)$$

$$p_{c,j} = a_c - q_{c,j} - \gamma_2^c q_{s,i} . \quad (4)$$

Stage 3: A Stackelberg Leader in Price Game

$$p_{s,i} = a_s - q_{s,i} - \gamma_3 q_{s,j} \text{, and} \quad (5)$$

$$p_{s,j} = a_s - q_{s,j} - \gamma_3 q_{s,i} . \quad (6)$$

The inverse demand functions in the first and the third stage are similar. In both stages, firms produce the same type of products; thus the constant term in equation (1) and (2), a_c, are the same; as well as, the constant term in equation (5) and (6), a_s, are the same. Moreover, the degrees of substitution in the first and the third stages are symmetrical. In the second stage, the constant term of inverse demand functions of firm i and firm j and the degrees of substitution in equation (3) and (4) are different since they produce two different types of products.

Assume that $0 < \gamma_2^s < \gamma_2^c < \gamma_3 < \gamma_1 < 1$ and that γ is greater than zero because two products are substitute products, and is less than one because the own-price effect dominates the cross-price effect (Shy, 1995). γ_1, which is the degree of substitution in the first stage, represents brand difference of firm i and j. γ_2^s and γ_2^c are degrees of substitution in the second stage of an inverse demand function of a sustainable product and an inverse demand function of a converntional product respectively which should represent the brand and product difference. However, γ_2^s and γ_2^c in this model represent only the product difference because the brand difference has a little effect compared to the product difference effect, and we would like to keep the model as simple as possible. γ_2^c is greater than γ_2^s because a consumer who would like to buy a sustainable product has a lower degree of substitution for a conventional product; while a consumer who buys a conventional product has a higher degree of product substitution for a sustainable product. For example, when conventional eggs are on sale, a consumer who intends to buy free-range eggs has difficulty switching to discounted conventional eggs. However, if free-range eggs are on sale and have a price close to a conventional product, a consumer who buys a conventional product will be easier to switch to buy discounted free-range eggs. γ_3 is the degree of substition in the third stage representing the brand difference and the brand loyalty for a leader firm in a new market. γ_3 is lower than γ_1 because γ_3 captures both brand difference and first-mover advantage (in the sense that consumers have brand loyalty to the leader's brand and launching the new sustainable product first supports leader's goodwill and reputation).

We also assume that the maximum willingness to pay for the conventional product, a_c is less than the maximum willingness to pay for the sustainable product, a_s. This implies that a consumer has a greater willingness to pay for a sustainable product than a conventional product. In addition, assume that the maximum willingness to pay is greater than the marginal cost (c). That is $a_c > c_{c,i}$, $a_c > c_{c,j}$, $a_s > c_{s,i}$, and $a_s > c_{s,j}$.

Results

The derivation for the profits in the first stage, $\pi_{c,i}^{1}*, \pi_{c,j}^{1}*$, the second stage, $\pi_{s,i}^{2}*, \pi_{c,j}^{2}*$, and the third stage, $\pi_{s,i}^{3}*, \pi_{s,j}^{3}*$ can be found in Appendix B. We compare profits at equilibrium (*) to find the conditons that allow the leader to get higher profits than the follower in each stage, and the conditions to move to the next stages. The comparisons will be made based on the restrictions about the maximum willngness to pay, the degress of substitution, and the marginal costs. Moreover, the author also uses the simulation results in order to better understand the standard findings and propositions.

Backward induction allows us to determine under what conditions do the manufacturers launch a sustainable product. That is the leader (firm i) considers the reaction of firm j when the leader launch a new sustainable product first, and then decides later whether to launch a new sustainable product or not. From Figure 2, the decision of the leader to launch a new sustainable product (move to the second stage) does not depend on only the comparison of the leader's profits in the first and the second stages, but also the comparison of the leader's profits in the first and the third stage. That is the analysis has to cover case 1 and 2 (Figure 2.1 and 2.2) when the follower also decides to lauch a new sustainable product after the leader's launch.

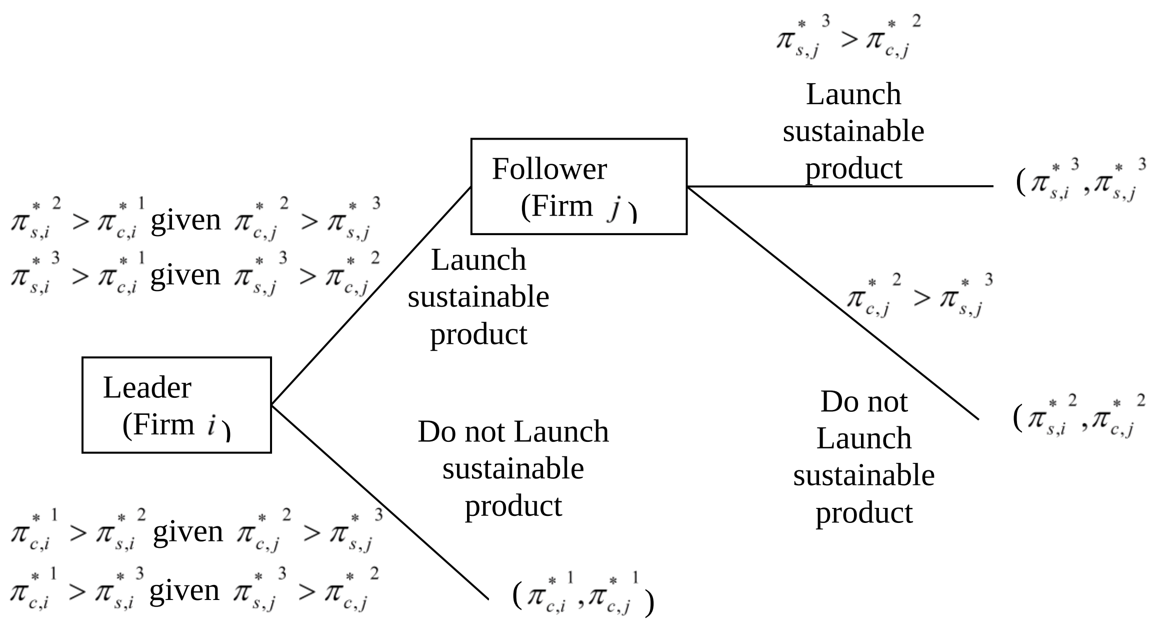


Figure 2: Backward induction decision tree

From Figure 2, there are four possible cases. **The first case** (Figure 2.1) is that the follower decides to launch a new sustainable product since $\pi_{s,j}^{3}* > \pi_{c,j}^{2}*$, and the leader also decides to launch a new sustainable product since $\pi_{s,i}^{3}* > \pi_{c,i}^{1}*$. **The second case** (Figure 2.2) is where the follower decides to launch a new sustainable product

($\pi_{s,j}{}^{3}* > \pi_{c,j}{}^{2}*$) when the leader decides to launch a new sustainable product. However, the leader finds that $\pi_{c,i}{}^{1}* > \pi_{s,i}{}^{3}*$, and decides not to launch a new sustainable product. Thus, there is no product launch. **The third case** (Figure 2.3) is that the follower decides to not launch a new sustainable product given the launch of the leader since $\pi_{c,j}{}^{2}* > \pi_{s,j}{}^{3}*$. Moreover, the leader also decides to not launch a new sustainable product since $\pi_{c,i}{}^{1}* > \pi_{s,i}{}^{2}*$. The **last case** (Figure 2.4) is that the follower decides to not launch a new sustaianable product ($\pi_{c,j}{}^{2}* > \pi_{s,j}{}^{3}*$) when the leader launches a new sustainable product; while, the leader decides to launch a new sustainable product since $\pi_{s,i}{}^{2}* > \pi_{c,i}{}^{1}*$.

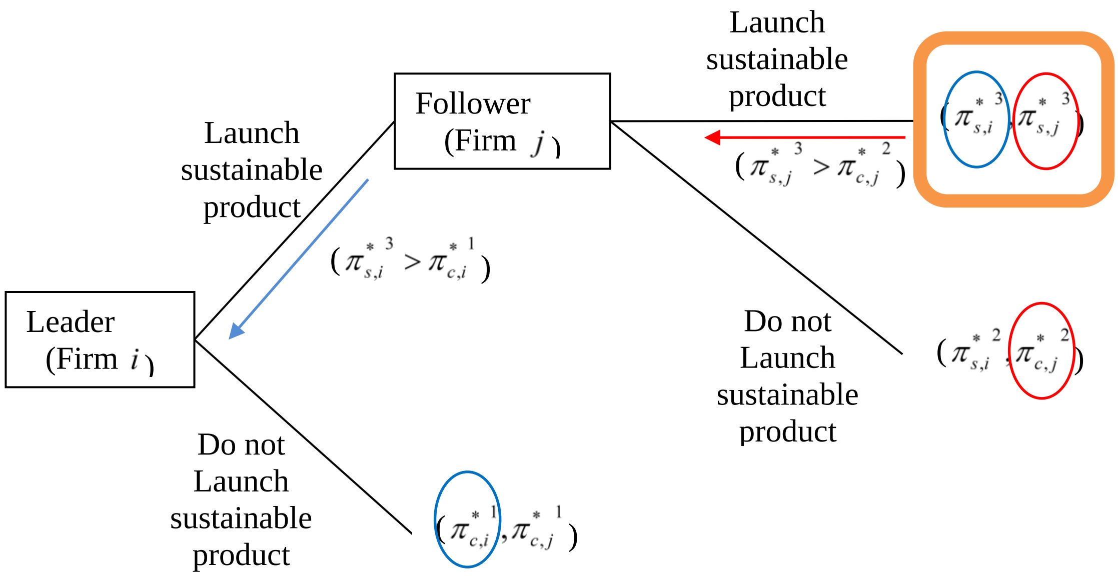


Figure 2.1: Case 1, leader and follower launch a new sustainable product.

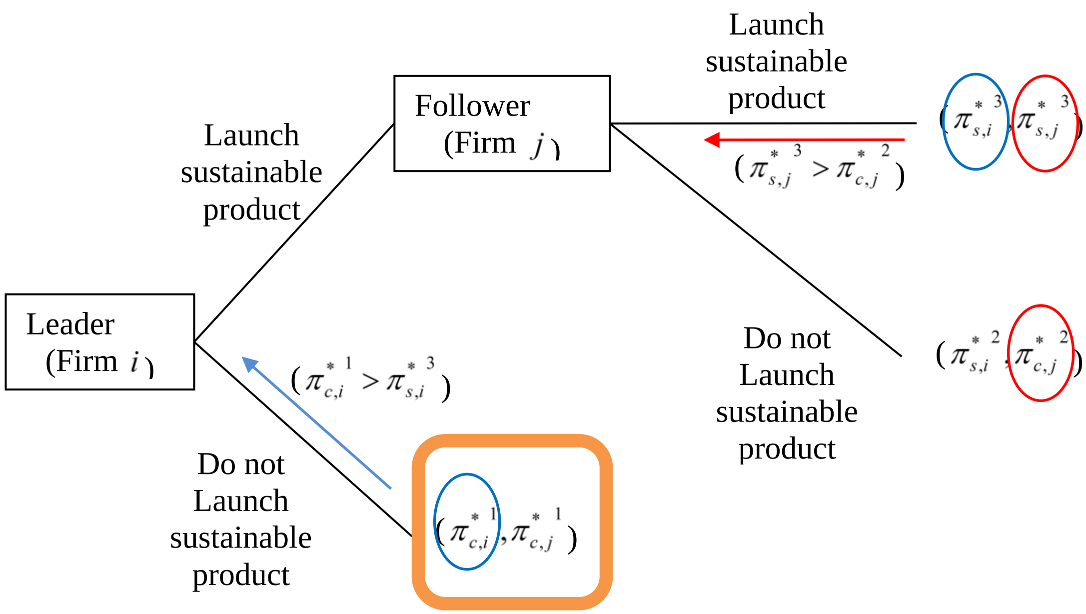


Figure 2.2: Case 2, no firm launches a new sustainable product and $\pi_{s,j}^{3} * > \pi_{c,j}^{2} *$.

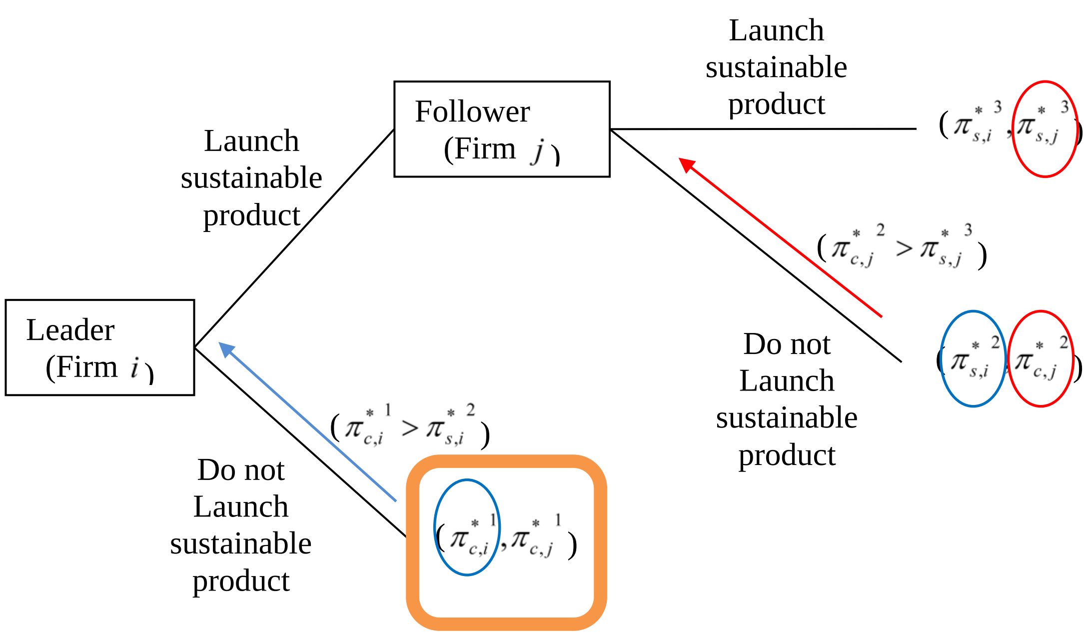


Figure 2.3: Case 3, no firm launches a new sustainable product and $\pi_{c,j}^{2} * > \pi_{s,j}^{3} *$.

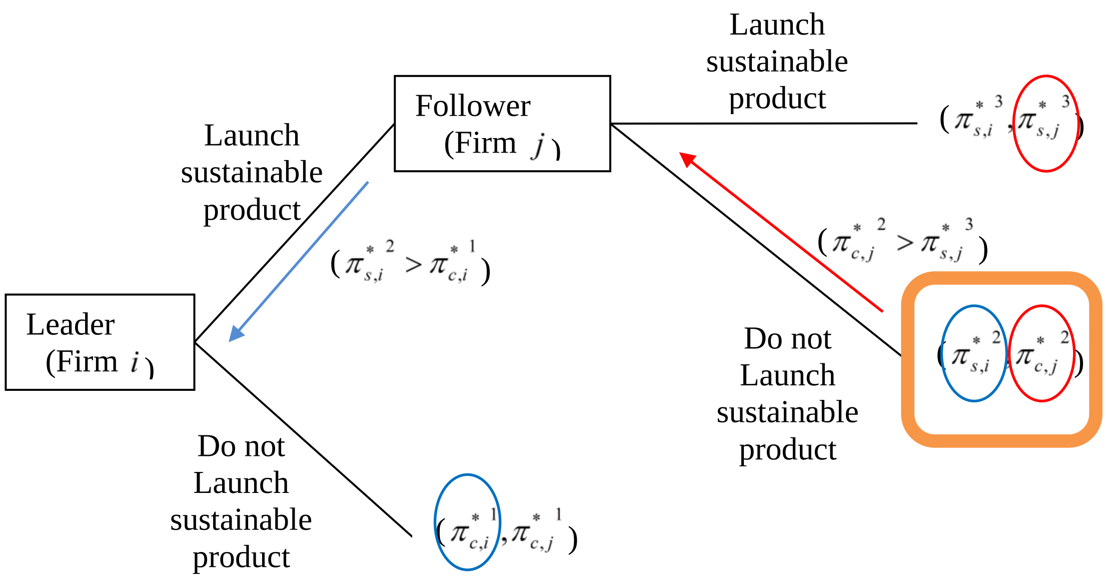
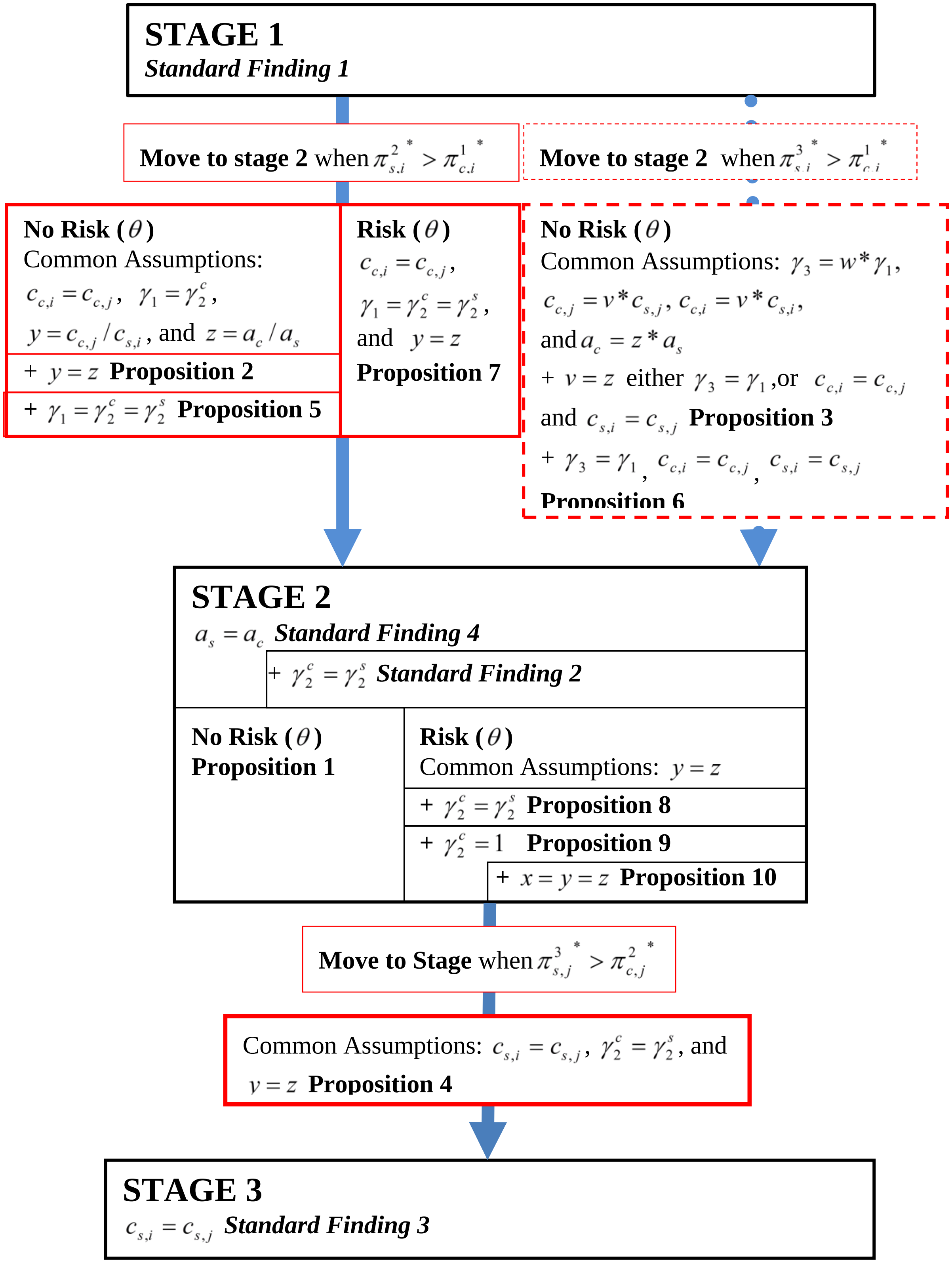


Figure 2.4: Case 4, only the leader firm launches a new sustainable product.

Figure 3 shows the diagram for the assumptions, the standard findings, and the propositions from the study in order to be easy to understand. The black boxes show the assumptions, the standard findings and the propositions from the comparison of the profits of two firms in the first, the second, and the stage; while, the red boxes show the assumptions, and the propositions regarding to moving to the next stage. There are two set of red boxes that contain the assumptions and the propositions regarding to moving to the second stage. That is there are two separate ways to move to the second stage: 1) comparing the leader's profits in the first and the second stage and 2) comparing the leader's profits in the first and the third stage which is consistent with the explaination for Figure 2. In addition, there are the uncertainty in the second stage (Appendix A); therefore, there is a risk variable (θ) in the boxes that involve the profits in the second stage.



Fiugre 3: Diagram for Standard Findings and Proposition

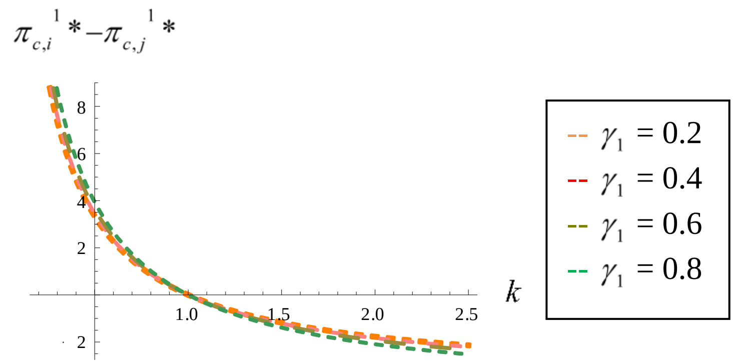
The next section presents the Standard Findings and Propositions[3] from comparing profits of both firms in each stage. Then, the Standard Findings and Propositions regarding to moving to the next stage is presented later

The Standard Findings and Propositions from comparing profits of both firms in each stage

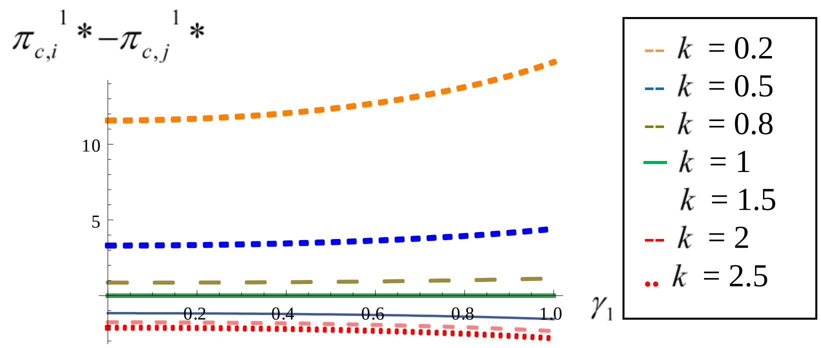
Standard Finding 1: In **the first stage**, marginal costs[4] determine which firm has a higher profit. Moreover, the difference in marginal costs and the degree of substitution γ_1 determine the diffence in the amount of profit. The larger difference in marginal costs and the larger degree of substitiution result to the larger difference in profit.
Explaination: Since γ_1 is symmetrical for both inverse demand functions in the first stage ($p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j}$, and $p_{c,j} = a_c - q_{c,j} - \gamma_1 q_{c,i}$), both firms face the same demand functions. Therefore, the firm who has a lower marginal cost will get a higher profit. Moreover, consumers easily switch to buy another product which has the lower cost and price when the degree of substitution (γ_1) is high. Figure 4 shows the summary idea from this Standard finding

Assume that $k = \frac{c_{c,i}}{c_{c,j}}$. When k equals 1, $c_{c,i}$ and $c_{c,j}$ have the same value, and when k is less (more) than 1, $c_{c,i}$ is less (more) than $c_{c,j}$. Figure 4.1 and 4.2 present the simulation results relate to this standard finding. Figure 4.1 shows that when the marginal cost of firm i is lower (higher) than the marginal cost of firm j or k < 1 (k > 1), the profit of firm i is greater (lower) than the profit of firm j or $\pi_{c,i}^{1} * - \pi_{c,j}^{1} * > 0$ ($\pi_{c,i}^{1} * - \pi_{c,j}^{1} * < 0$). From Figure 4.2, when the degree of substitution (γ_1) changes, the sign of the difference in profits of two firms ($\pi_{c,i}^{1} * - \pi_{c,j}^{1} *$) does not change; however when γ_1 increases the absolute value of $\pi_{c,i}^{1} * - \pi_{c,j}^{1} *$ will increase.

[3] The proof of all Standard findings and Propositions are contained in Appendix C.
[4] In our analysis, the marginal costs are the same as the variable costs.



Fiugre 4.1: the simulation results to show the relationship between the difference in profits ($\pi_{c,i}^{1}* - \pi_{c,j}^{1}*$), and the difference in costs (k)



Fiugre 4.2: the simulation results to show the relationship between the difference in profits ($\pi_{c,i}^{1}* - \pi_{c,j}^{1}*$), and the degree of substiion (γ_1)

Fiugre 4: the simulation results to show the relationship between the difference in profits, and the degree of substiion or the difference in cost

Standard Finding 2: When the degree of substitution of a conventional product and a sustainable product are the same in the second stage, $\gamma_2^c = \gamma_2^s$, and the intercept of the inverse demand functions are the same for the conventional product and the sustainable product ($a_s = a_c$), ***the follower will have a higher profit than the leader***.

Explaination: If the leader has higher costs to produce a sustainable product, consumers are willing to pay the premium for the the sustainable product and consumers think that the conventional and sustainable products are the same, the leader will get a lower profit than a follower.

Proposition 1: In **the second stage**, we define that $x = \frac{\gamma_2^s}{\gamma_2^c}$, $y = \frac{c_{c,j}}{c_{s,i}}$, $z = \frac{a_c}{a_s}$, 0 < $x, y,$ and z < 1 (we will use this definition for the whole analysis), the leader will get a higher profit than the follower's if

a. $y < z$ and, $\frac{c_{c,j}}{a_c} < \frac{y[2(1-z)+(1-xz)\gamma_2^c + x(z-1)\left(\gamma_2^c\right)^2]}{z[2(1-y)+(1-xy)\gamma_2^c + x(y-1)\left(\gamma_2^c\right)^2]}$, or

b. $y = z$, or

c. $z < y$ and, $\frac{c_{c,j}}{a_c} < \frac{y[-2(1+z)+(1+xz)\gamma_2^c + x(z+1)\left(\gamma_2^c\right)^2]}{z[-2(1+y)+(1+xy)\gamma_2^c + x(y+1)\left(\gamma_2^c\right)^2]}$.

In case a. and b., **the leader will have a higher probability of getting higher profit than the follower as y goes higher, and z gets smaller.**

Explaination: y equals $\frac{c_{c,j}}{c_{s,i}}$ which is $c_{c,j}$ /($c_{c,i}$ + the additional cost for the sustainable product). An increase in y can imply a lower marginal cost for the sustainable production or the higher marginal cost of the conventional product, so there is a higher probability that the leader who produces the sustainable product will get a higher profit. In addition, z equals a_c /(a_c + the additional maximum willingness to pay for the sustainable product). A decrease in z implies a higher amount of additional maximum willingness to pay for the sustainable product; hence, the leader gets higher price and profit when producing the sustainable product.

When $y = z$, $\frac{c_{c,j}}{a_c} = \frac{c_{s,i}}{a_s}$ implies that the additional cost to produce the sustianable product can be coverd by the additioanal maximum willingness to pay for the sustainable product. Figure 5 shows that $D_{s,i}^2$ and $D_{c,j}^2$ are demand curves for the sustainable product of firm i and for the conventional product of firm j in the second stage. $D_{s,i}^2$ has the same slope and is just a parallel shift outward from $D_{c,j}^2$, meaning they face a greater demand but similar elasticity along the demand curve. The y-intercept of $D_{s,i}^2$ is higher than the y-intercept of $D_{c,j}^2$ because $a_s > a_c$ and $q_{s,i}^{2}* > q_{c,j}^{2}*$. When $y = z$ the equilibrium quantity and price of firm i is greater than equilibrium the quantity and price of firm j ($q_{s,i}^{2}* > q_{c,j}^{2}*$ and $p_{s,i}^{2}* > p_{c,j}^{2}*$), and the profit of firm i is greater than the profit of firm j (area $p_{s,i}^{2}*$ab$c_{s,i}$ > area $p_{c,j}^{2}*$cd$c_{c,j}$).

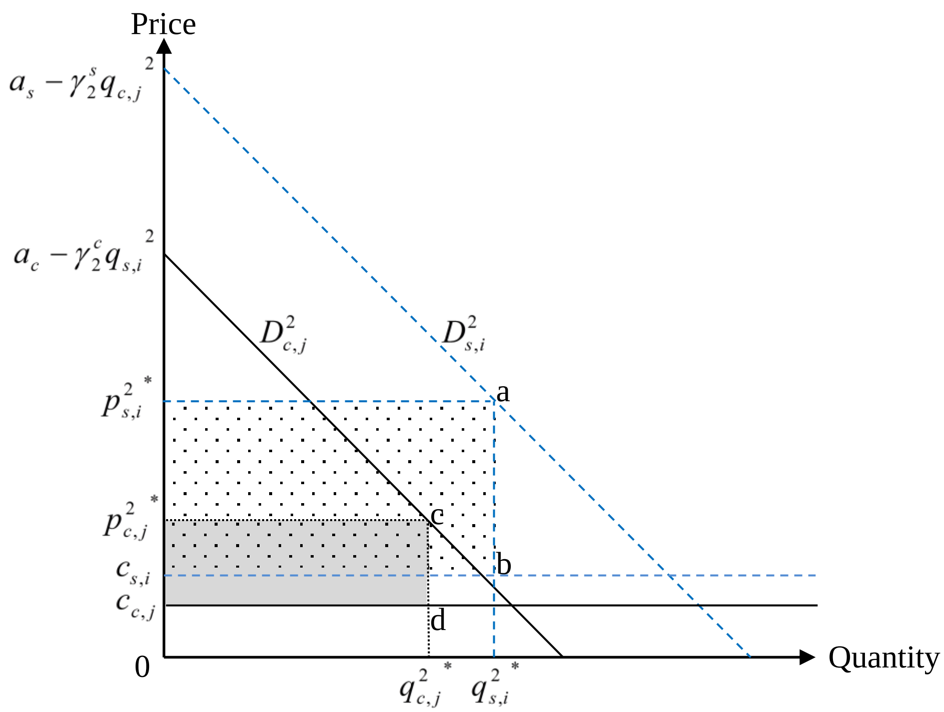
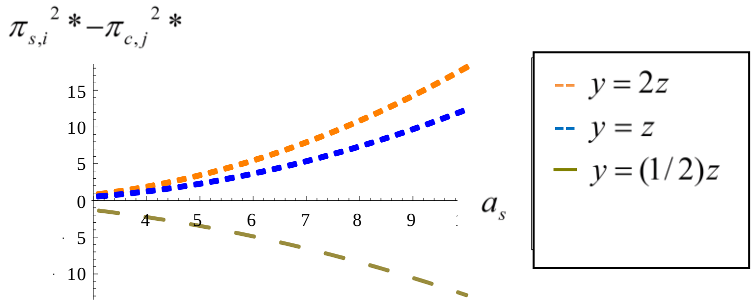


Figure 5: The graph to compare the profits of two firms in the second stage

When $y > z$, the equilibrium quantity of the leader is greater than the equilibrium quantity of the follower ($q_{s,i}{}^2 * > q_{c,j}{}^2 *$), and also the margin of the leader is greater than the margin of the follower ($p_{s,i}{}^2 * - c_{s,i}$) > ($p_{c,j}{}^2 * - c_{c,j}$). Therefore, the profit of the leader is actually greater than the profit of the follower. The condition $\frac{c_{c,j}}{a_c} < \frac{y[-2(1+z)+(1+xz)\gamma_2^c + x(z+1)\left(\gamma_2^c\right)^2]}{z[-2(1+y)+(1+xy)\gamma_2^c + x(y+1)\left(\gamma_2^c\right)^2]}$ is a mathematical condition to confirm that the y-intercept is greater than the marginal cost ($a_c - \gamma_2^c q_{s,i}{}^2 > c_{c,j}$). This is because when y is higher, it implies the higher value of $c_{c,j}$; therefore, there is a condition to make sure that the conventional market still exists.

Figure 6 shows the simulation results for the relationship between $\pi_{s,i}{}^2 * - \pi_{c,j}{}^2 *$, and a_s when $y > z$, $y = z$, and $y < z$. According to the figures from the egg industry, the simulation shows that $\pi_{s,i}{}^2 *$ will be less than $\pi_{c,j}{}^2 *$ when $y < z$.



Fiugre 6: The simulation results to show the relationship between $\pi_{s,i}^{2}* - \pi_{c,j}^{2}*$, and a_s when $y > z$, $y = z$, and $y < z$

Standard Finding 3: In **the third stage**, when both firms have the same (marginal) cost ($c_{s,i} = c_{s,j}$), ***the follower will get a higher profit with a lower price and a higher quantity***. This is the same result as Boyer and Moreaux, 1987; Shy, 1995; and Denicolo and Lambertini 1996.

Explaination: Under the Stackleberg price leadership model, the leader sets the price first, and the follower set the price after observing the market. Under the same marginal cost, the follower will under cut the price of the leader in order to get a higher market share and a higher profit. That is, in the strackleberg price leadership model, the follower gets a second-mover advantage in the sense that the follower has more information about the price of the leader and can set the price to get a higher profit than the leader's profit.

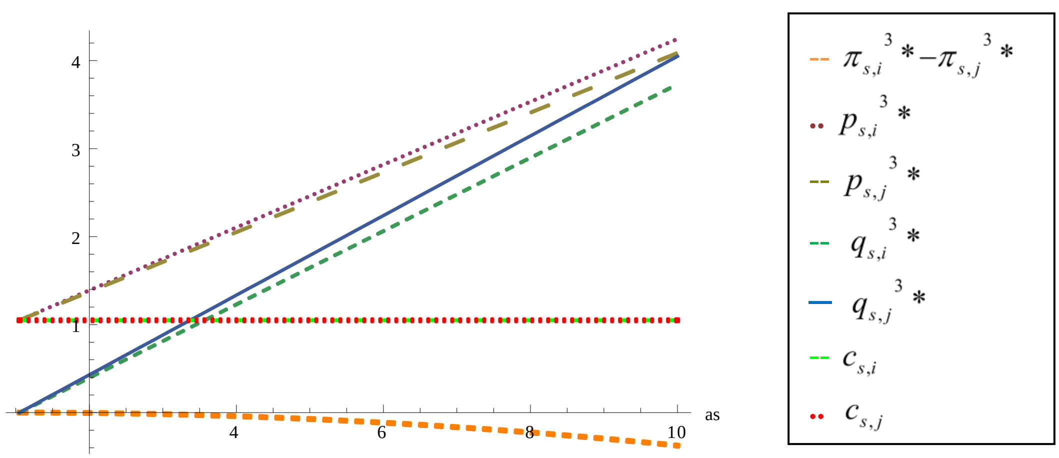


Figure 7.1: γ_3 =0.5

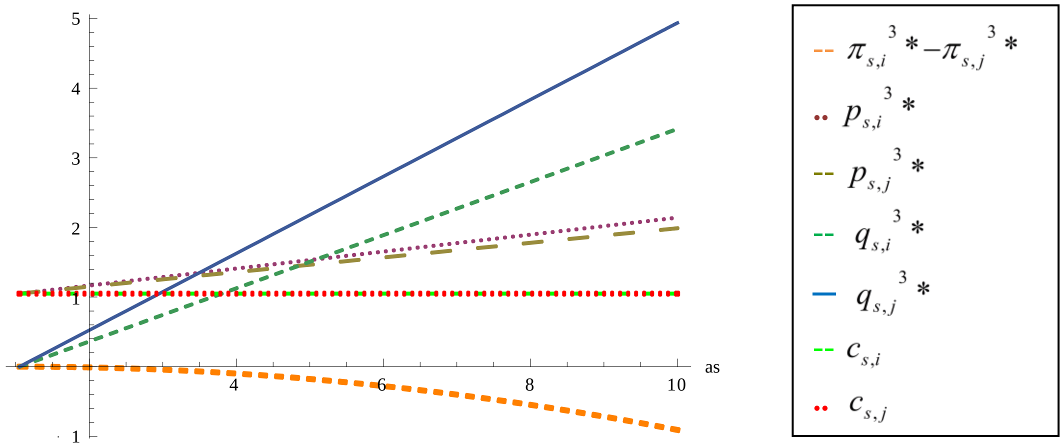


Figure 7.2: γ_3 =0.9

Fiugre 7: the simulation results to compare the profits, prices, quantities, and costs of two firms in the third stage

Figure 7 shows the simulation results comparing the profits, prices, quantities, and costs of two firms in the third stage. The equilibrium profit of firm i is less than the equilibrium profit of firm j ($\pi_{s,i}^{3}* - \pi_{s,j}^{3}* < 0$) when $c_{s,i} = c_{s,j}$. Moreover, $p_{s,j}^{3}*$ is less than $p_{s,i}^{3}*$ since the follower tries to under cut the price to get the higher market share ($q_{s,j}^{3}* > q_{s,i}^{3}*$) and profit. When the market expands (a high value of a_s), the difference in equilibrium profits, prices and quantities are higher. Moreover, when γ_3 is higher, the difference in the equilibrium quantities ($q_{s,j}^{3}* - q_{s,i}^{3}*$) is higher because consumers easily switch to buy a product with lower price when they perceive that the products from two firm are the same.

The Standard Findings and Propositions regarding to moving to the next stage

From Proposition 1, the interesting restriction to use in the analysis is $\frac{c_c}{c_s} = \frac{a_c}{a_s}$ or $y = z$, or $v = z$ where $v = \frac{c_{c,i}}{c_{s,i}} = \frac{c_{c,j}}{c_{s,j}}$ or the ratio of the marginal cost of the conventional product over the marginal cost of the sustainable product equals the maximum willingness to pay for the conventional product over the maximum willingness to pay for the sustainable product $\left(\frac{c_c}{c_s} = \frac{a_c}{a_s}\right)$.

Proposition 2: When $\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s}$, $\gamma_1 = \gamma_2^c$, and $c_{c,i} = c_{c,j}$, the leader will decide to launch a new sustainable product (move to the second stage) in order to get a higher profit.

Proposition 3: When $\frac{c_{c,i}}{c_{s,i}} = \frac{c_{c,j}}{c_{s,j}} = \frac{a_c}{a_s}$, and either $\gamma_1 = \gamma_3$ or $c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$, the leader will decide to launch a new sustainable product (move to the second stage) in order to get a higher profit.

Explaination: Proposition 2 expresses the restrictions that inspire the leader to launch a new sustainable product by comparing the profit of the leader in the first stage and the second stage.

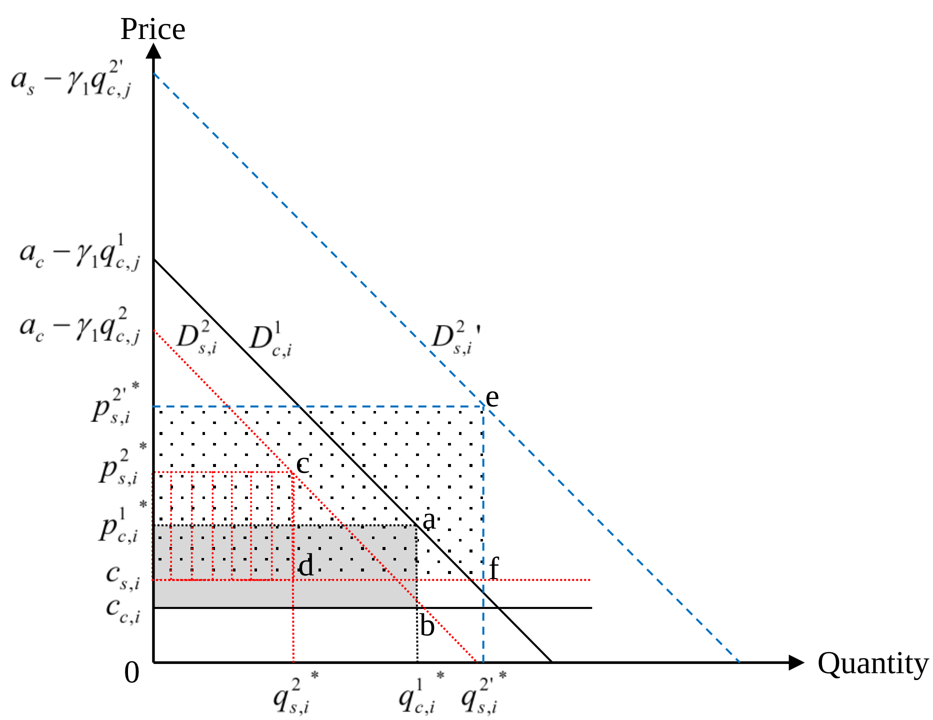


Figure 8: The graph to compare the profits of the leader in the first and the second stage

Figure 8 shows that the leader launches a new sustainable product, but the consumers are not willing to pay more for the sustainable product ($a_c = a_s$), the demand function will shift from $D_{c,i}^1$ to $D_{s,i}^2$. $D_{c,i}^1$ has the same slope as $D_{s,i}^2$ which equal to -1, but the y-intercept will be lower because $q_{c,j}^2$ is higher than $q_{c,j}^1$. That is when the leader has the higher cost, the leader has to set the higher price which allows the follower to get a higher market share. The leader's profit in the first stage which equals to the area $p_{c,i}^{1*}$ ab

$c_{c,i}$ can be less or more than the leader's profit in the second stage (the area $p_{c,i}^{2\,*}$ cd $c_{s,i}$)[5]. However, if consumers have a higher maximum willingness to pay for the sustainable product (or the market is expanded) ($a_s > a_c$ and $y = z$); then, the leader will get the higher profit when launcing the sustainable product. Figure 6 shows that when the demand is shifted from $D_{c,i}^{1}$ to $D_{s,i}^{2}$', the leader will get the higher profit (area $p_{c,i}^{2'\,*}$ ef $c_{s,i}$ > area $p_{c,i}^{1\,*}$ ab $c_{c,i}$).

Under the same restrictions as in Proposition 2 ($\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s}$, $\gamma_1 = \gamma_2^c$, and $c_{c,i} = c_{c,j}$), Figure 9 shows that $\pi_{s,i}{}^{2}*$ is greater than $\pi_{c,j}{}^{2}*$ ($\pi_{s,i}{}^{2}* - \pi_{c,i}{}^{1}* > 0$). Moreover, when the sustainable market expands (a_s is higher), $\pi_{s,i}{}^{2}* - \pi_{c,j}{}^{2}*$ is higher.

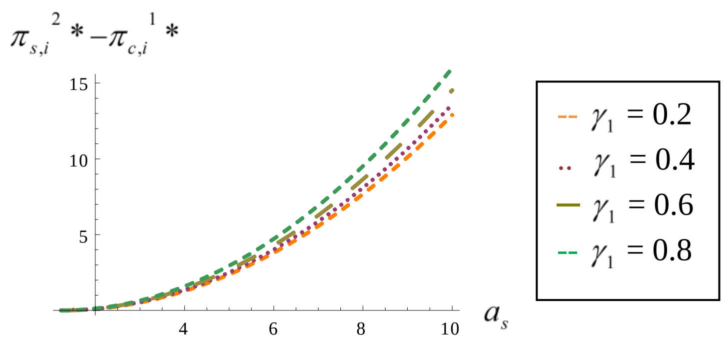


Figure 9: The simulation results to compare the profits of the leader in the first and the second stage

Proposition 3 expresses the restrictions that make the leader launches a new sustainable product by comparing the profit of the leader in the first stage and the third stage.The simulation results to compare between the leader's profit in the first and the third stage are shown in Figure 10. Figure 10.1 shows the simulation results when $\gamma_1 = \gamma_3$, but neither $c_{c,i} = c_{c,j}$ nor $c_{s,i} = c_{s,j}$; while, Figure 10.2 shows the simulation results when $c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$, but $\gamma_1 \neq \gamma_3$. The interpretation and the intuition of this proposition are similar to the interpretaion and the intuition of Proposition 2.

[5] This is similar to the result in Proposition 6.

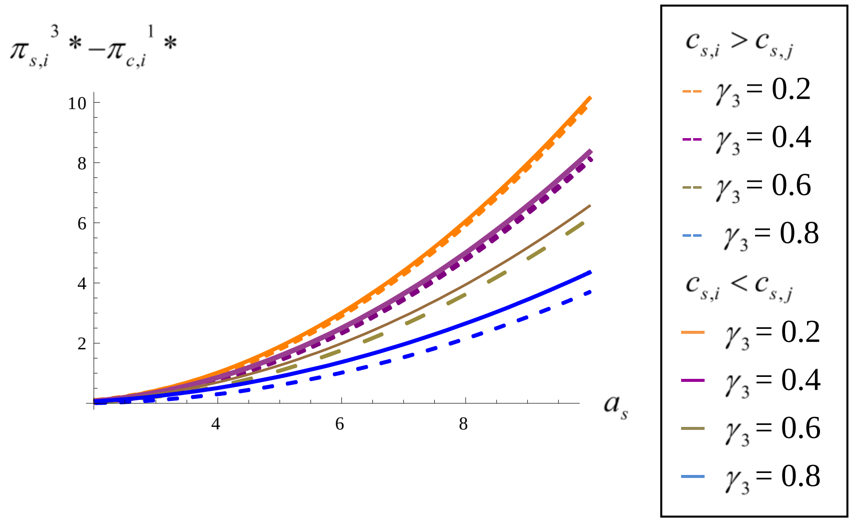


Figure 10.1: Assume that $\gamma_1 = \gamma_3$.

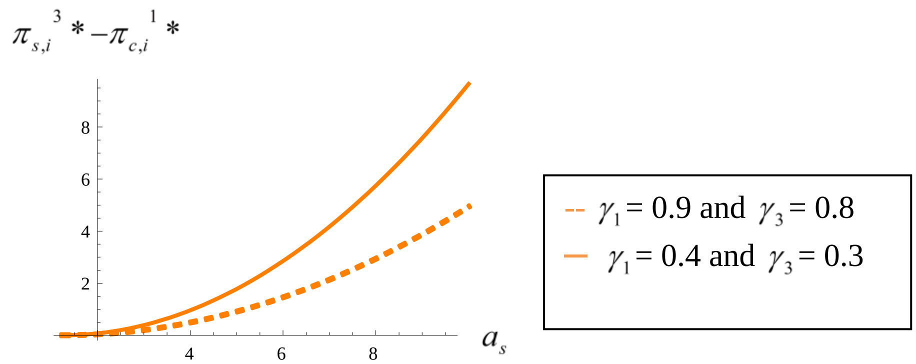


Figure 10.1: Assume that $c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$.

Figure 10: The simulation results to compare the profits of the leader in the first and the third stage

Proposition 4: When $\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s}$, $\gamma_2^c = \gamma_2^s = \gamma_3$, and $c_{s,i} = c_{s,j}$, the follower will decide to launch a new sustainable product (move to the third stage) if

a. $0 < \gamma_2^s \le 0.746478$, or

b. $0.746478 < \gamma_2^s < 1$ and $\frac{0.25[(\gamma_2^s - 2)((\gamma_2^s + 3)(\gamma_2^s - 4)\gamma_2^s - 8)\gamma_2^s - 16]}{((\gamma_2^s)^2 - 2)^2} < y < 1$.

Explaination: The intuitions for Proposition 4a. is that when the conventional product can substitue for the sustainable product at a low level ($0 < \gamma_2^s \le 0.746478$), the follower will get a higher profit when launch a new sustainable product. That is when the product of the follower can substitute for the leader's product at a low degree, the follower will launch a new product to grab the market share from the leader in order to get higher profits. Proposition 4b shows that under the high value of degree of substitution between the conventional and sustainable products ($0.746478 < \gamma_2^s < 1$), the follower will get a higher profit when launch a new product if the marginal cost of the sustainable product is low enough such that $\frac{0.25[(\gamma_2^s - 2)((\gamma_2^s + 3)(\gamma_2^s - 4)\gamma_2^s - 8)\gamma_2^s - 16]}{((\gamma_2^s)^2 - 2)^2}$ is lower than y.

Figure 11 shows the simultion results that compare the follower's profits in the second and the third stage. Figure 11.1 and Figure 11.2 shows the results that are consistent with Proposition 4a and 4b, respectively. That is $\pi_{s,j}^{3}*$ is always higher than $\pi_{c,j}^{2}*$ when $0 < \gamma_2^s \leq 0.746478$. Moreover, when $0.746478 < \gamma_2^s < 1$, the higher value of y increases the probability that $\pi_{s,j}^{3}* > \pi_{c,j}^{2}*$.

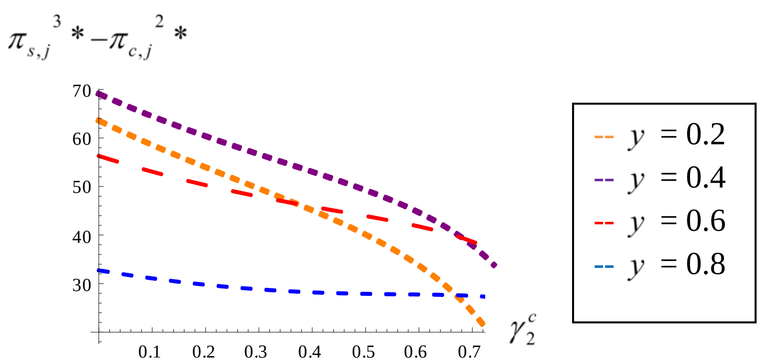


Figure 11.1: $0 < \gamma_2^s \leq 0.746478$

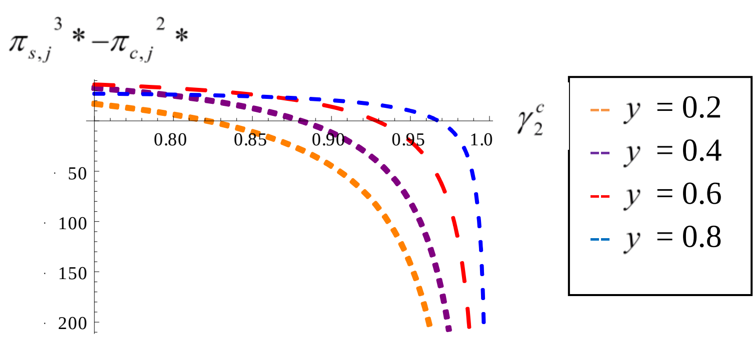


Figure 11.2: $0.746478 < \gamma_2^s < 1$

Figure 11: The simulation results to compare the follower's profits in the second and the third stage

Next, we will analyze our model when $\frac{c_c}{c_s} \neq \frac{a_c}{a_s}$.

Proposition 5: When $\gamma_1 = \gamma_2^c = \gamma_2^s$, and $c_{c,i} = c_{c,j}$, the leader will decide to launch a new sustainable product (move to the second stage) if

a. $y = z$, or

b. $0 < \gamma_2^c \leq \sqrt{3} - 1$ and

i. $y < z$ and $a_c - c_{c,j} < a_s - c_{s,i}$, or

ii. $z < y$ and $\frac{c_{c,j}}{a_c} < \frac{y}{z}\left(\frac{(\gamma_2^c)^2 + (\gamma_2^c(\gamma_2^c + 2) - 2)z - 2}{(\gamma_2^c)^2 + (\gamma_2^c(\gamma_2^c + 2) - 2)y - 2}\right)$, or

c. $1 > \gamma_2^c > \sqrt{3} - 1$ and

i. $y < z$ and ($\frac{y}{z}\left(\frac{(\gamma_2^c)^2 + (\gamma_2^c(\gamma_2^c + 2) - 2)z - 2}{(\gamma_2^c)^2 + (\gamma_2^c(\gamma_2^c + 2) - 2)y - 2}\right) < \frac{c_{c,j}}{a_c}$ or $a_c - c_{c,j} < a_s - c_{s,i}$), or

ii. $z < y$.

Explaination: Figure 12 shows the conditions that allow the leader to have higher profits when launching a new sustainable product. The intuition of Proposition 5a is the same as the intuition of Proposition 2. For part b and c of Proposition 5, it is easier for the leader to decide to launch a new sustainable product when γ_2^c has a high value. That is from Figure 12, the conditions to make $\pi_{s,i}^{2}* > \pi_{c,i}^{1}*$ on the right hand side are easier to satisfied than the conditions on the left hand side. When $z < y$, the leader will decide to launch a new sustainable product if $\gamma_2^c > \sqrt{3} - 1$, but if $\gamma_2^c \leq \sqrt{3} - 1$, the leader will decide to lauch a new sustainable product when the condition

$\frac{c_{c,j}}{a_c} < \frac{y}{z}\left(\frac{(\gamma_2^c)^2 + (\gamma_2^c(\gamma_2^c + 2) - 2)z - 2}{(\gamma_2^c)^2 + (\gamma_2^c(\gamma_2^c + 2) - 2)y - 2}\right) = A$ is also satisfied. When $y < z$, the leader will decide to launch a new sustainable product if the difference between the maximum willingness to pay and the marginal cost for a sustainable product is high enough (higher than the difference between the maximum willingness to pay and the marginal cost for a conventional product, or $a_s - c_{s,i} > a_c - c_{c,j}$). Moreover, if $\gamma_2^c > \sqrt{3} - 1$ and $y < z$, the leader can decide also to launch a new sustainable product when $A < \frac{c_{c,j}}{a_c}$. The intuition is that when the degree of substitution is high enough ($\gamma_2^c > \sqrt{3} - 1$), consumers are easier to switch to purchase a new sustainable product.

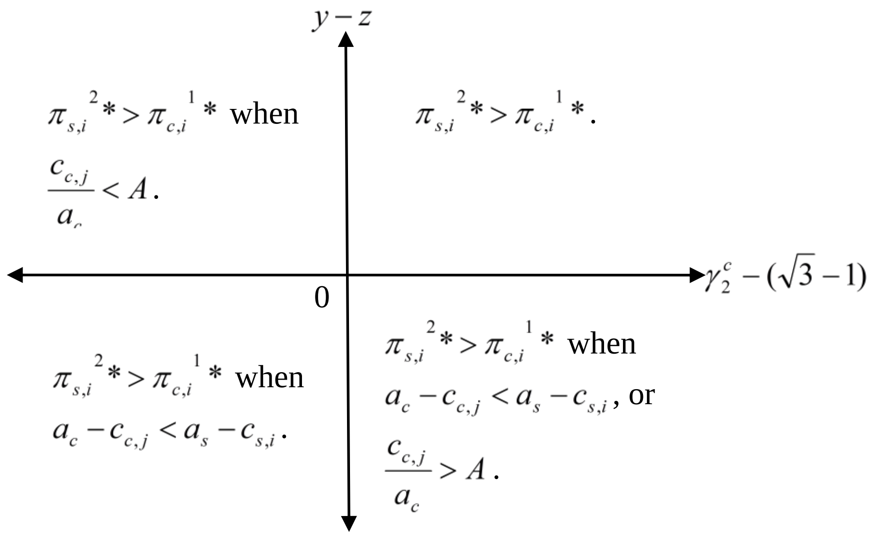


Figure 12: The graph to show the conditions that makes $\pi_{s,i}{}^{2}* > \pi_{c,i}{}^{1}*$

Figute 13 shows the relationship between $\pi_{s,i}{}^{2}* - \pi_{c,i}{}^{1}*$ and γ_2^c; that is the higher value of γ_2^c ($\gamma_2^c > \sqrt{3}-1$), the higher probability that $\pi_{s,i}{}^{2}*$ is greater than $\pi_{c,i}{}^{1}*$ which is consistent witht the explaination for Figure 12.

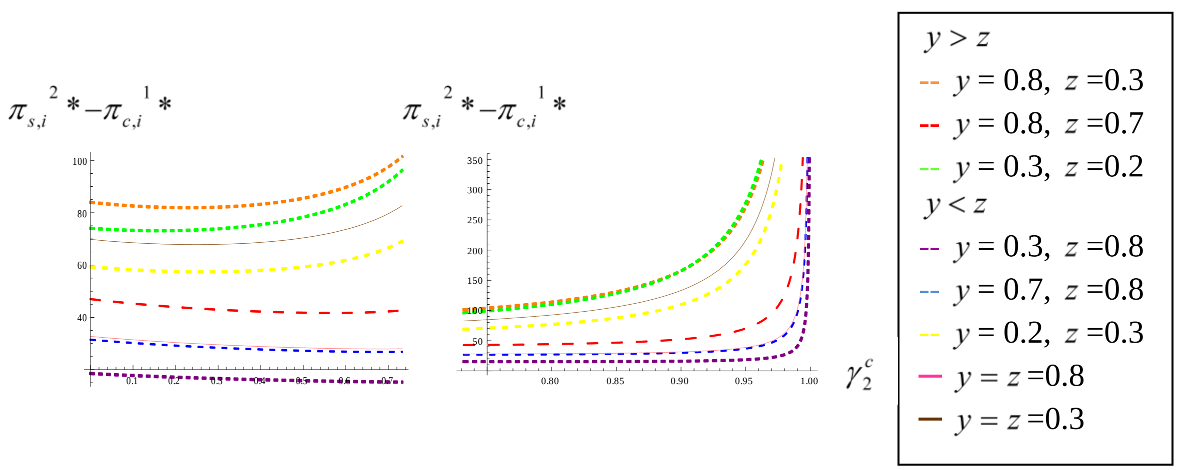


Figure 13: The relationship between $\pi_{s,i}{}^{2}* - \pi_{c,i}{}^{1}*$ and γ_2^c in the range 0 < $\gamma_2^c \le \sqrt{3}-1$ (left) and 1 > $\gamma_2^c > \sqrt{3}-1$ (right)

Proposition 6: When $\gamma_1 = \gamma_3$, $c_{c,i} = c_{c,j}$, and $c_{s,i} = c_{s,j}$, the leader will decide to launch a new sustainable product (move to the second stage) if

a. $v = z$, OR

b. ($v < z$ or $v > z$) and

$$a_s > c_{s,j} + 2\sqrt{2}\sqrt{-\frac{c_{s,j}^{\ 2}(\gamma_3^{\ 2}-4)^2(\gamma_3^{\ 2}-2)(v-z)^2}{((\gamma_3^{\ 2}-4)^2+8(\gamma_3^{\ 2}-2)z^2)^2} + \frac{8c_{s,j}(\gamma_3^{\ 2}-2)(v-z)z}{(\gamma_3^{\ 2}-4)^2+8(\gamma_3^{\ 2}-2)z^2}}.$$

Explaination: The intuition for Proposition 7a is the same as the intuition in Proposition 2. The intuition in part b is that the maximum willingness to pay for the sustainable product has to be higher than the marginal cost of the sustainable product, such that $(a_s - c_{s,j} > 2\sqrt{2}\sqrt{-\frac{c_{s,j}^{\ 2}(\gamma_3^{\ 2}-4)^2(\gamma_3^{\ 2}-2)(v-z)^2}{((\gamma_3^{\ 2}-4)^2+8(\gamma_3^{\ 2}-2)z^2)^2} + \frac{8c_{s,j}(\gamma_3^{\ 2}-2)(v-z)z}{(\gamma_3^{\ 2}-4)^2+8(\gamma_3^{\ 2}-2)z^2}})$ in order to make the leader's profit in the third stage be higher than the leader's profit in the first stage.

Figure 14 shows the simulation results for the relationship between $\pi_{s,i}^{\ 3}* - \pi_{c,i}^{\ 1}*$ and a_s. That is the higher value of a_s increases the probability that $\pi_{s,i}^{\ 3}*$ is greater than $\pi_{c,i}^{\ 1}*$ which is consistent with Proposition 6b.

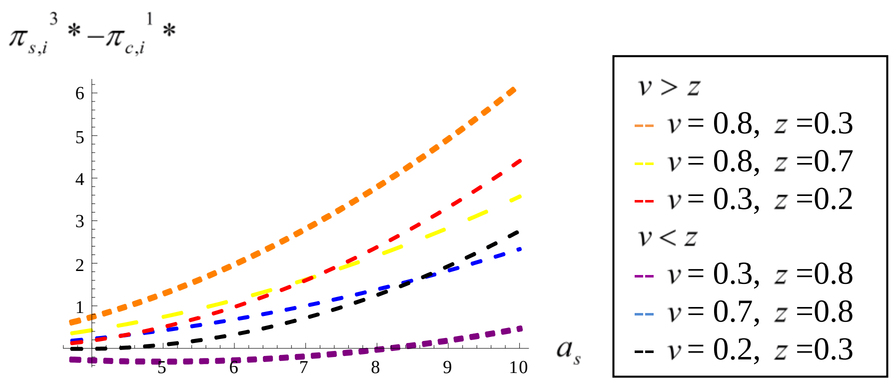


Figure 14: The simulation results to show the relationship between $\pi_{s,i}^{\ 3}* - \pi_{c,i}^{\ 1}*$ and a_s

The expansion of the model to cover the uncertainty on the maximum willingness to pay for a sustainable product is presented in Appendix A.

Simulation for the Egg Industry

There are many studies analyzied about the price premium of a free-range or cage free egg. The price premium of a free-range or cage-free egg ranges from 47.72% to 105.15% as shown in Table 1.

Table 1: The price premium of a free-range or cage-free egg and the source of information

Source	Price premium of a free-rang or cage-free egg (%)
Chang, Lusk and Norwood , 2010	57
Mintel, 2008	60
Satimanon and Weatherspoon, 2010	47.72
United Egg Producer, --- (based on the USDA weekly retail shell egg)	105.15

Promar internatioanl (2009) collected the data about the additional cost for a free-rang or cage-free egg from several sources. The additional cost for the free-range or cage-free egg was range from 20% to 66%. In addition, Summer (2008) presented that the difference of production costs between cage production system ($ 0.745 per dozen) and non-cage production system ($ 1.05 per dozen) equal to 40.94% . There are no data about egg manufacturer' production costs. Therefore, we assume that all of the costs in the manufacture level for the sustainable and the conventional eggs are the same except the cost for the raw material, eggs from the farmers. Moreover, we will use $ 0.745 as a cost for the conventional egg or assume that the egg price sold by farmers is the same as the cost. This is for simplicity and we are not interested in farmers' margin.

There are two scenarios for the simulation which are the best case scenario and the worst case scenario. The price premium and the additional cost for a free-range or cage-free egg in the best case scenario are 105.15% and 20%, respectively. On the other hand, the price premium and the additional cost for a free-range or cage-free egg in the worst case scenario are 40.72% and 66%. To comply with the variables in the model, we will set up $c_{c,j}$ equal to $ 0.745 per dozen, $\frac{c_{c,j}}{c_{s,i}}$ in the second stage equal to 1/1.66 (1/1.2) and the propotion of prices in the second stage, $\frac{p_{s,i}^{2}*}{p_{c,j}^{2}*}$, equal to 1.4772 (2.0515) for the worst (best) case scenario. Moreover, we assume that $c_{c,i} = c_{c,j}$, $c_{s,i} = c_{s,j}$, and $\gamma_1 = \gamma_2^c = \gamma_2^s = \gamma_3 = \gamma$ for the simplicity.

Simulation Results

The simulation results support the leader and the follower to launch a new sustainable product, a sustainable egg. That is the leader's profit when launching the new sustainable egg is higher than the profit when producing the conventional egg, and so do the follower. This is consistent with case 1 in Figure 2.1.

The equilibrium profits, prices, and quantities of the worst case and the best case have similar trend and sign, except the amount of the equilibrium variables. Figure 15 shows that when the maximum willingness to pay for the sustainable egg (a_s) is high or the market of the sustainable egg has a big size, the leader and the follower have a high profit when launching the sustianable egg. Figure 15 also shows that when the degree of substitution between the conventional and the sustainable eggs (γ) closes to 1, the leader and the follower have a lower profit when launching the sustainable egg; however, in both cases, the worst case and the best case, the leader and the follower still have higher profits than the profits when producing the conventional product. This is because if consumers perceive that the conventional and the sustainable egg are similar, consumers easily switch to buy the conventional egg which has a lower cost and price.

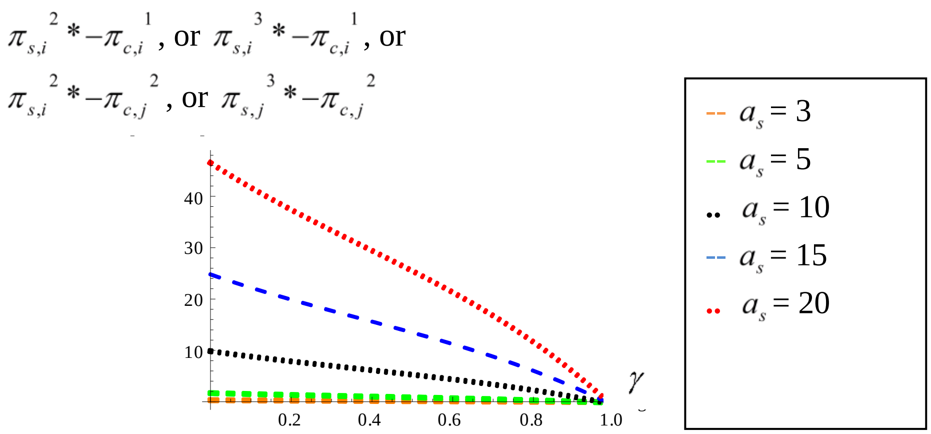


Figure 15: The relationship between the difference between the profits of launching the sustainable egg and producing the conventional egg, and the degree of substitution between the sustainable and the conventional eggs

Backward induction is used to explain the decision making to move to the next stage or the decision making whether the firm should launch the sustainable egg. Therefore, we consider the follower's decision making to launch the sustainable egg first; then, the leader will make the decision given the follower's decision. Figure 16 shows that the follower's profit when launching the sustainable egg is higher than the follower's profit when producing the conventional egg ($\pi_{s,j}^{3}* - \pi_{c,j}^{2}* > 0$); therefore, **the follower decides to launch the sustainable egg.** The equilibrium price of the conventional egg in the second stage is the lowest price comparing to other prices in the second and the third stage ($p_{c,j}^{2}* < p_{s,i}^{2}*$, $p_{c,j}^{2}* < p_{s,i}^{3}*$, and $p_{c,j}^{2}* < p_{s,j}^{3}*$) because consumers are willing to pay more for the sustainable egg. The price of the sustainable egg of the follower in the third stage is less than the price of the sustainable egg of the leader in the third stage ($p_{s,j}^{3}* < p_{s,i}^{3}*$) as the explaination in Standard Finding 3. When the degree of substitution between two types of eggs is low (Figure 16.1), the price of the sustainable egg in the second stage is higher than the prices of the sustainable egg in the third stage ($p_{x,i}^{2}* > p_{s,i}^{3}* > p_{s,j}^{3}*$). The reason is that consumers perceive that two types of eggs are different; therefore, the price of the sustainable egg is high and higher than the prices of the sustainable egg in the third stage. However, When the degree of substitution between two types of eggs is high (Figure 16.2), the price of the sustainable egg in the second stage is low and lower than the leader's price of the sustainable egg in the third stage or even lower than the follower's price of the sustainable egg in the third stage

($p_{s,i}^{3}* > p_{s,i}^{2}* > p_{s,j}^{3}*$ or $p_{s,i}^{3}* > p_{s,j}^{3}* > p_{x,i}^{2}*$). This is because consumers do not realize the difference between two types of eggs, so the leader's price of the sustainable egg in the second stage is low.

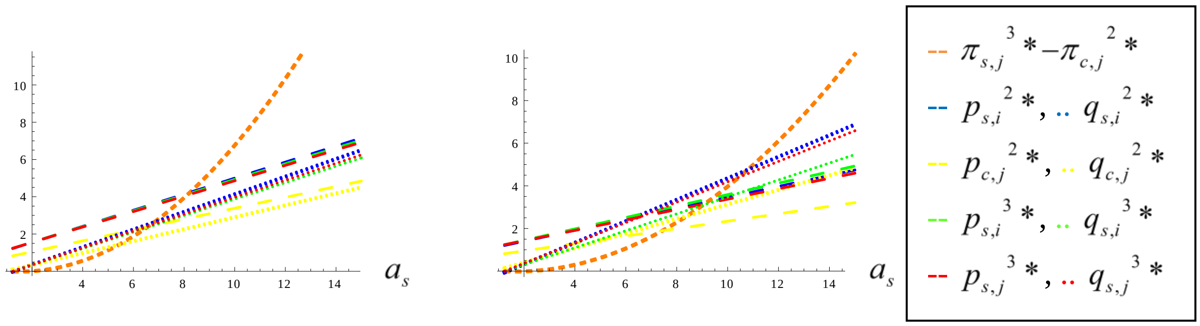


Figure 16.1: $\gamma = 0.3$ **Figure 16.2**: $\gamma = 0.7$

Figure 16: The relationship between the equilibrium variables in the first and the third stage and the maximum willingness to pay for the sustainable egg

Next, the leader makes a decision making to launch the sustainable egg given the information that the follower decide to launch the sustainable egg when the leader launchs the sustainable eggs. Figure 17 compares the equilibrium variables in the first and the third stage. Figure 17 shows that the leader's profit in the third stage ($\pi_{s,i}^{3}*$) is higher than the leader's profit in the first stage ($\pi_{c,i}^{1}$); hence, **the leader decides to launch the sustainable egg.** The equilibrium prices and quantities in the first stage are the same for both firms ($p_{c,i}^{1}* = p_{c,j}^{1}*$ and $q_{c,i}^{1}* = q_{c,j}^{1}*$) since we assume the same marginal costs for the conventional egg ($c_{c,i} = c_{c,j}$). The equilibrium price of the conventional egg in the first stage ($p_{c,i}^{1}*$) is lower than the equilibrium prices in the third stage ($p_{s,i}^{3}*$ and $p_{s,j}^{3}*$) because consumers are willing to pay more for the sustainable egg ($a_s > a_c$).

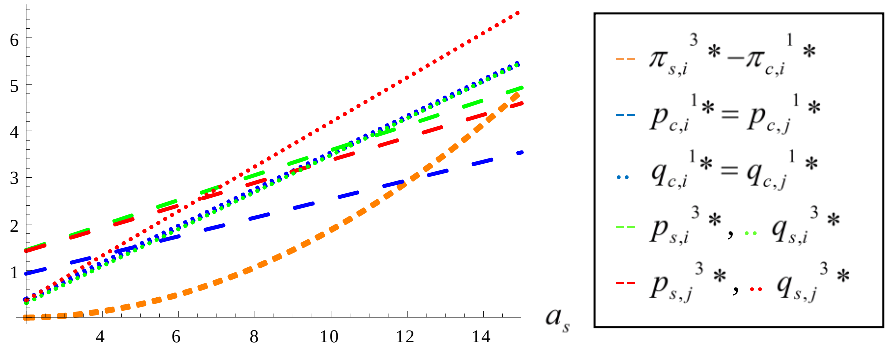


Figure 17: The relationship between the equilibrium variables in the first and the third stage and the maximum willingness to pay for the sustainable egg

In sum, according to the prices and the costs of the conventional and the sustainable egg from the literatue, both the leader and the follower egg manufacture firms should launch the sustainable egg to get higher profits. Therefore, we can observe the expansion of the sustainable egg market during the past few years.

Conclusion

We construct the model for food manufactures' decision making to launch a new sustainable product to the market. The main factors that influence firms to launh the new sustainable product are that consumers are willing to pay more for the sustainable product, and perceive that the conventional and the sustainable products are different. Morover, the firms has more probability to get higher profit when launching the new sustainable product if the ratio of the cost over the maximum willingness to pay for the conventional product is equal to or greater than the same ratio of the sustainable product.

We use the values of costs and prices of the conventional egg and the sustainable egg for the simulation part in order to have better understanding about the firms' decision making. According to the figures from the literature, egg manufacturers should launh the sustainable egg in order to get higher profits

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Appendix:

Appendix A: The expansion of the model for the uncertainty in demand side

The author focuses on the expansion of the model for the uncertainty in demand side. That is whether consumers would like to pay more for the sustainable product is still questionable for food manufactures. This issue is very important for manufactures' decision making to launch a new sustainable product. Many articles about market entry concerned about the uncertainty on a demand or a profitability (Maggi, 1996; Hirokawa, and Sasaki, 2001; Creane, and Jeitschko, 2010).

The reasons why the uncertainty in demand side is explicily represented in the model are: 1) The author would like to make a model as simple as possible; therefore, the uncertainty in supply side is not included in the model, and 2) The firm can control about costs, but not consumer's demand. The uncertainty is added only in the second stage because of three reasons. First, **the first stage** is a current situation. Firms know the exising demand; hence, there is no uncertainty. Second, there is an uncertainty in **the second stage**. It has never had the new product in the target market before the second stage, so a firm can not expect about the consumer's maximum willingness to pay for the new product. Third, since the new sustainable product was launched already in the second stage, the firms know the consumer's maximum willingness to pay for the new product already. Therefore, there is no uncertainty in **the third stage**.

Many authors applied the real option method to consider uncertainty of launching a new product or investing in reserch and development a new product (Han, Smit, and Ankum, 1993; Grenadier, 2000; Botteron, Chesney, and Gibson-Asner, 2003; Russo, Cardillo, and Perito, 2003; Schwartz, 2004; Kijima, and Shibata, 2005). However, the real option is not suitable to our model since the real option is usually set up to deal with a pattern of continuous time and infinite period; while, the model in this paper is a three-stage discrete time game.

The idea of the binary distribution of maximum willingness to pay of a sustainable product (a_s) is adapted from the demand function in Creane, and Jeitschko (2010). That is $P(Q,\alpha) = \alpha\overline{P}(Q) + (1-\alpha)\underline{P}(Q)$ where α is the consumers' perception of the fraction of high quality products, and $\overline{P}(Q)$ ($\underline{P}(Q)$) is an inverse demand of products of known high (low) quality. An inverse demand function of sustainable product in the second stage is $p_{s,i} = \left[\theta a_s + (1-\theta)a_c\right] - q_{s,i} - \gamma_2^s q_{c,j}$ where θ represents the leader firm's expectation that consumers would like to pay more for a new sustainable product, and θ has a value between zero and one. According to the inverse demand function defined above, the expected maximum willingness to pay for a sustainable product is defined in Figure 18.

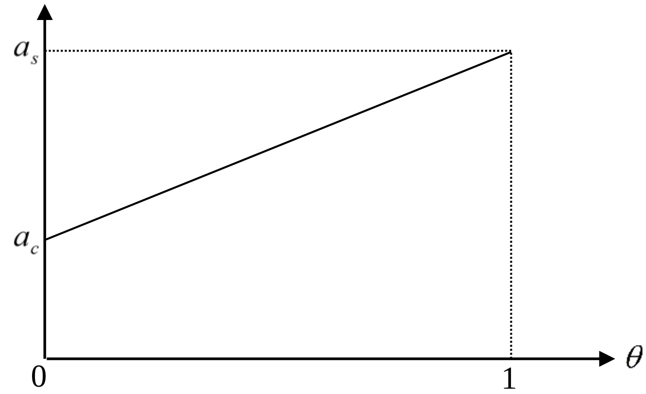

Figure 18: The relationship between the expected maximum willingness to pay for a sustainable product and the probability that the leader expect that consumers are willing to pay more for the sustainable product (θ)

The resutlts when the uncertainty is added into the model is shown as follows:

Standard Finding 4: When an intercept of an inverse demand function are the same for a conventional product and a sustainable product ($a_s = a_c$), results of a case with risk and without risk are the same (θ is disappear). This is because a risk in the model represents via a maximum willingness to pay for a sustainable product. When amounts of maximum willingness to pay for a sustainable product and a conventional product are the same, the uncertainty represented by θ is disappeared.
Explaination: This assumption represents the worst case scenario that is the leader firm expects to get zero premiums from the new product. Therefore, there is no uncertainty defined in the model since the firm assumes the lowest maximum willingnes to pay for the sustainable product already.

Proposition 7: When $\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s}$, $\gamma_1 = \gamma_2^c = \gamma_2^s$, and $c_{c,i} = c_{c,j}$, a leader will decide to launch a new sustainable product (move to the second stage) if

$$0 < \frac{c_{c,j}}{a_c} < \theta \text{ or } \frac{((\gamma_1)^2 + \gamma_1 - 2)2z - ((\gamma_1)^2 - 2)(z-1)\theta}{(\gamma_1)^2 + (\gamma_1(2+\gamma_1) - 2)z - 2} < \frac{c_{c,i}}{a_c} < 1.$$

Proposition 8: When $\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s}$, and a degree of substitution of a conventional product and a sustainable product are the same $\gamma_2^c = \gamma_2^s$, the leader will get a higher profit than the follower if $0 < \frac{c_{c,j}}{a_c} < \theta$ or $\frac{(1-z)\theta + 2z}{(1+z)} < \frac{c_{c,j}}{a_c} < 1$.

Proposition 9: When $\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s}$, and a sustainable product can perfectly substitute with a conventional product ($\gamma_2^c = 1$),the leader will get the higher profit than the follower if $0 < \frac{c_{s,i}}{a_s} < \frac{(x-1)z-(x-3)(z-1)\theta}{2z+x-3}$ or $\frac{\theta(1-z)+3z}{1+2z} < \frac{c_{c,j}}{a_c} < 1$.

Proposition 10: When $\frac{c_{c,j}}{c_{s,i}} = \frac{a_c}{a_s} = \frac{\gamma_2^s}{\gamma_2^c}$, and a sustainable product can perfectly substitute with a conventional product ($\gamma_2^c = 1$), the leader will get the higher profit if $0 < \frac{c_{s,i}}{a_s} < \frac{z+(3-z)\theta}{3}$ or $\frac{(1-z)\theta+3z}{1+2z} < \frac{c_{c,j}}{a_c} < 1$.

Explaination: From Proposition 7, the leader will get a higher profit when launching a new sustainable product if the probability to get the premium from consumers is high enough ($0 < \frac{c_{c,i}}{a_c} < \theta$), or if the marginal cost of the conventional product over the maximum willingness to pay for the conventional product is high enough ($\frac{((\gamma_1)^2+\gamma_1-2)2z-((\gamma_1)^2-2)(z-1)\theta}{(\gamma_1)^2+(\gamma_1(2+\gamma_1)-2)z-2} < \frac{c_{c,i}}{a_c} < 1$). Intuitively, Propsition 7 presents that the leader will decide to launch a new sustainable product when the probability to get the price premium for a new sustainable product is high enough, or the marginal cost of a conventional product (the maximum willingness to pay for a conventioanl product) is high (low) enough.

The intuition of Propsition 8, 9, and 10 are similar to the intuition of Proposition 7. That is the first condition of all propositions present that the leader has a higher profit than the follower when the probability to get the premium from consumers (θ) is high enough; and the second conditions of the propositions implies that the leader has a higher profit than the follower when the marginal cost of the conventional product over the maximum willingness to pay for the conventional product is high enough

Appendix B: The calculation for the profits in each stage

The First Stage:

In this stage, both firms produce conventional product and choose a price as a strategy simultaneously. Firm i and firm j's inverse demand functions are:

$$p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j}\text{, and} \tag{1}$$

$$p_{c,j} = a_c - q_{c,j} - \gamma_1 q_{c,i}\,. \tag{2}$$

Hence, the demand functions are: $q_{c,i} = \dfrac{(1-\gamma_1)a_c + \gamma_1 p_{c,j} - p_{c,i}}{1-(\gamma_1)^2}$, and

$q_{c,j} = \dfrac{(1-\gamma_1)a_c + \gamma_1 p_{c,i} - p_{c,j}}{1-(\gamma_1)^2}$. Then, we can set firm i's profit function (π_i) as:

$\pi_i = \left(\dfrac{(1-\gamma_1)a_c + \gamma_1 p_{c,j} - p_{c,i}}{1-(\gamma_1)^2}\right)(p_{c,i} - c_{c,i})$, where $c_{c,i}$ and $c_{c,j}$ are marginal costs to produce a conventional product of firm i and firm j, respectively. Then, we solve a problem by finding the first order condition (FOC) to get the reaction functions.

FOC.

$$\frac{\partial \pi_i}{\partial p_{c,i}} = 0,$$

$$\left(\frac{(1-\gamma_1)a_c + \gamma_1 p_{c,j} - p_{c,i}}{1-(\gamma_1)^2}\right) - \left(\frac{p_{c,i} - c_{c,i}}{1-(\gamma_1)^2}\right) = 0,$$

$$p_{c,i} = \left(\frac{(1-\gamma_1)a_c + \gamma_1 p_{c,j} + c_{c,i}}{2}\right). \tag{9}$$

Similarly,

$$p_{c,j} = \left(\frac{(1-\gamma_1)a_c + \gamma_1 p_{c,i} + c_{c,j}}{2}\right). \tag{10}$$

(9) and (10) represents reaction functions of firm i and firm j. From (9) and (10) we get the optimal prices in stage 1 ($p_{c,i}^{1}*$, and $p_{c,j}^{1}*$) as follows: $p_{c,i}^{1}* =$ $\left(\dfrac{\left(2-\gamma_1-(\gamma_1)^2\right)a_c + \gamma_1 c_{c,j} + 2c_{c,i}}{\left(4-(\gamma_1)^2\right)}\right)$, and $p_{c,j}^{1}* = \left(\dfrac{\left(2-\gamma_1-(\gamma_1)^2\right)a_c + \gamma_1 c_{c,i} + 2c_{c,j}}{\left(4-(\gamma_1)^2\right)}\right)$.

Plug the equilibrium prices into the demand functions, then we get the equilibrium quantities in the first stage ($q_{c,i}^{1}*$, and $q_{c,j}^{1}*$) as follows:

$$q_{c,i}^{1}* = \frac{(2-\gamma_1 - \gamma_1^2)a_c + \gamma_1 c_{c,j} + (\gamma_1^2 - 2)c_{c,i}}{4 - 5\gamma_1^2 + \gamma_1^4}\text{, and}$$

$$q_{c,j}^{1}* = \frac{(2-\gamma_1 - \gamma_1^2)a_c + \gamma_1 c_{c,i} + (\gamma_1^2 - 2)c_{c,j}}{4 - 5\gamma_1^2 + \gamma_1^4}.$$

Then, firm i and firm j 's profits in the first stage ($\pi_i^{1}*$, and $\pi_j^{1}*$) are:

$$\pi_i^{\ 1} * \quad = \frac{\left[a_c\left(2-\gamma_1-\gamma_1^2\right)-\left(2-\gamma_1^2\right)c_{c,i}+\gamma_1 c_{c,j}\right]^2}{\left(\gamma_1^2-4\right)^2\left(1-\gamma_1^2\right)}, \text{ and}$$

$$\pi_j^{\ 1} * \quad = \frac{\left[a_c\left(2-\gamma_1-\gamma_1^2\right)-\left(2-\gamma_1^2\right)c_{c,j}+\gamma_1 c_{c,i}\right]^2}{\left(\gamma_1^2-4\right)^2\left(1-\gamma_1^2\right)}.$$

The Second Stage:

The leader firm which is assumed to be firm i launches a new sustainable product into the market, while the follower (firm j) still supplies a conventional product. Both firms choose price as the strategy simultaneously. An inverse demand function of firm i who produces sustainable product is,

$$p_{s,i} = a_s - q_{s,i} - \gamma_2^s q_{c,j}, \qquad (3)$$

and an inverse demand function of firm j who produces conventional product is,

$$p_{c,j} = a_c - q_{c,j} - \gamma_2^c q_{s,i}, \qquad (4)$$

where $\gamma_2^s < \gamma_2^c$. From the inverse demand functions, we get the demand functions as: $q_{s,i} = \frac{\left(a_s - \gamma_2^s a_c\right) - p_{s,i} + \gamma_2^s p_{c,j}}{1-\gamma_2^s\gamma_2^c}$, and $q_{c,j} = \frac{\left(a_c - \gamma_2^c a_s\right) - p_{c,j} + \gamma_2^c p_{s,i}}{1-\gamma_2^s\gamma_2^c}$. Then, firm i's profit function is, $\pi_i = (p_{s,i} - c_{s,i})q_{s,i} - I_{s,i} = (p_{s,i} - c_{s,i})\frac{\left(a_s - \gamma_2^s a_c\right) - p_{s,i} + \gamma_2^s p_{c,j}}{1-\gamma_2^s\gamma_2^c}$. Firm i's first order condition is as follows:

FOC.
$$\frac{\partial \pi_i}{\partial p_{s,i}} = 0,$$

$$\frac{(c_{s,i} - p_{s,i}) + \left(a_s - \gamma_2^s a_c\right) - p_{s,i} + \gamma_2^s p_{c,j})}{1-\gamma_2^s\gamma_2^c} = 0,$$

$$p_{s,i} = \frac{\left(a_s - \gamma_2^s a_c\right) + c_{s,i} + \gamma_2^s p_{c,j}}{2}.$$

Similarly, $p_{c,j} = \frac{\left(a_c - \gamma_2^c a_s\right) + c_{c,j} + \gamma_2^c p_{s,i}}{2}$. Next, from the reaction functions of firm i and j, we can get the equilibrium prices in the second stage ($p_{s,i}^{\ 2}*$, and $p_{c,j}^{\ 2}*$), which are: $p_{s,i}^{\ 2}* = \frac{\left(2a_s - \gamma_2^s a_c - \gamma_2^s\gamma_2^c a_s\right) + 2c_{s,i} + \gamma_2^s c_{c,j}}{\left(4-\gamma_2^s\gamma_2^c\right)}$, and $p_{c,j}^{\ 2}* = \frac{\left(2a_c - \gamma_2^c a_s - \gamma_2^s\gamma_2^c a_c\right) + 2c_{c,j} + \gamma_2^c c_{s,i}}{\left(4-\gamma_2^s\gamma_2^c\right)}$. Then, the equilibrium quantities in the second stage ($q_{s,i}^{\ 2}*$ and $q_{c,j}^{\ 2}*$) are: $q_{s,i}^{\ 2}* = \frac{(2a_s - a_c\gamma_2^s - a_s\gamma_2^s\gamma_2^c) + \gamma_2^s c_{c,j} + (\gamma_2^s\gamma_2^c - 2)c_{s,i}}{4 - 5\gamma_2^s\gamma_2^c + \left(\gamma_2^s\right)^2\left(\gamma_2^c\right)^2}$, and

$q_{c,j}{}^{2}* = \frac{(2a_c - a_s\gamma_2^c - a_c\gamma_2^s\gamma_2^c) + \gamma_2^c c_{s,i} + (\gamma_2^s\gamma_2^c - 2)c_{c,j}}{4 - 5\gamma_2^s\gamma_2^c + (\gamma_2^s)^2(\gamma_2^c)^2}$. Also when we plug all equilibrium prices and equilibrium quantities into profit functions, we get profits at equilibrium of both firms ($\pi_i{}^2*$, and $\pi_j{}^2*$): $\pi_i{}^2* =$

$\frac{\left[\left(a_s\left(\gamma_2^s\gamma_2^c - 2\right) + a_c\gamma_2^s\right) - \gamma_2^s c_{c,j} + \left(2 - \gamma_2^s\gamma_2^c\right)c_{s,i}\right]^2}{\left(\gamma_2^s\gamma_2^c - 4\right)^2\left(1 - \gamma_2^s\gamma_2^c\right)}$, and $\pi_j{}^2* =$

$\frac{\left[\left(a_c\left(\gamma_2^s\gamma_2^c - 2\right) + a_s\gamma_2^c\right) - \gamma_2^c c_{s,i} + \left(2 - \gamma_2^s\gamma_2^c\right)c_{c,j}\right]^2}{\left(\gamma_2^s\gamma_2^c - 4\right)^2\left(1 - \gamma_2^s\gamma_2^c\right)}$.

The Third Stage:

In this stage, the follower firm (firm j) also supplies a new sustainable product. Both firms still choose prices as a choice variable. However, it is a sequential game in this stage. That is the leader will choose its own price first and then the follower decides to choose the price later. That is, the leader will put the reaction function of firm j into its own objective function in order to protect the new market. An inverse demand function of firm i who is the leader is,

$$p_{s,i} = a_s - q_{s,i} - \gamma_3 q_{s,j}, \qquad (5)$$

and an inverse demand function of firm j who follows to produce sustainable product is,

$$p_{s,j} = a_s - q_{s,j} - \gamma_3 q_{s,i}. \qquad (6)$$

The demand functions in this stage are: $q_{s,i} = \frac{(1-\gamma_3)a_s + \gamma_3 p_{s,j} - p_{s,i}}{1-(\gamma_3)^2}$, and $q_{s,j} = \frac{(1-\gamma_3)a_s + \gamma_3 p_{s,i} - p_{s,j}}{1-(\gamma_3)^2}$. Then, we find firm j's reaction function in order to put it into firm i's objective function in the next step (backward induction). Firm j's profit function is: $\pi_j = (p_{s,j} - c_{s,j})q_{s,j} - I_j = \left(p_{s,j} - c_{s,j}\right)\frac{(1-\gamma_3)a_s + \gamma_3 p_{s,i} - p_{s,j}}{1-(\gamma_3)^2}$. Firm j's first order condition is as follows:

FOC.
$$\frac{\partial \pi_j}{\partial p_{s,j}} = 0,$$
$$\frac{(c_{s,j} - p_{s,j}) + (1-\gamma_3)a_s + \gamma_3 p_{s,i} - p_{s,j}}{1-\gamma_3^2} = 0,$$
$$\frac{(1-\gamma_3)a_s + \gamma_3 p_{s,i} + c_{s,j}}{2} = p_{s,j}. \qquad (11)$$

The reaction function of firm j is shown in equation 11. Firm i's profit function is,

$\pi_i = (p_{s,i} - c_{s,i})q_{s,i} = \left(p_{s,i} - c_{s,i}\right)\dfrac{(1-\gamma_3)a_s + \gamma_3 p_{s,j} - p_{s,i}}{1-(\gamma_3)^2}$. Then, we substitute reaction function of firm j (equation (11)) into firm i's profit function, $\pi_i =$ $\left(\dfrac{p_{s,i} - c_{s,i}}{1-(\gamma_3)^2}\right)\left[(1-\gamma_3)a_s + \gamma_3\left(\dfrac{(1-\gamma_3)a_s + \gamma_3 p_{s,i} + c_{s,j}}{2}\right) - p_{s,i}\right]$. From the first order condition, the equilibrium price of firm i in the third stage is $p_{s,i}{}^3* =$ $\dfrac{(2-\gamma_3-\gamma_3^2)a_s + \left(2-\gamma_3^2\right)c_{s,i} + \gamma_3 c_{s,j}}{2(2-\gamma_3^2)}$. Substitute $p_{s,i}{}^3*$ into the reation function of firm j; then, we get the equilibrium price of firm j in the third stage as: $p_{s,j}{}^3* =$ $\dfrac{(4-2\gamma_3-3\gamma_3^2+\gamma_3^3)a_s + \left(4-\gamma_3^2\right)c_{s,j} + (2-\gamma_3^2)\gamma_3 c_{s,i}}{4(2-\gamma_3^2)}$. Substitute the equilibrium prices into the demand function, so the equilibrium quantities are: $q_{s,i}{}^3* =$ $\dfrac{(2-\gamma_3-\gamma_3^2)a_s - \left(2-\gamma_3^2\right)c_{s,i} + \gamma_3 c_{s,j}}{4(1-\gamma_3^2)}$, and $q_{s,j}{}^3* =$ $\dfrac{\left(4-2\gamma_3-3\gamma_3^2+\gamma_3^3\right)a_s + \left(2-\gamma_3^2\right)\gamma_3 c_{s,i} - \left(4-3\gamma_3^2\right)c_{s,j}}{4\left(2-3\gamma_3^2+\gamma_3^4\right)}$. Finally, the equilibrium profits in the third stage ($\pi_{s,i}{}^3*$, and $\pi_{s,j}{}^3*$) are:

$$\pi_{s,i}{}^3* = \frac{\left[(2-\gamma_3-\gamma_3^2)a_s - (2-\gamma_3^2)c_{s,i} + \gamma_3 c_{s,j}\right]^2}{8\left(2-3\gamma_3^2+\gamma_3^4\right)}, \text{ and}$$

$$\begin{aligned}\pi_{s,j}{}^3* = &\left[\frac{1}{16\left(\gamma_3^2-2\right)^2\left(1-\gamma_3^2\right)}\right]\{\left(\left(4-2\gamma_3-3\gamma_3^2+\gamma_3^3\right)a_s\right)^2 \\ &-2\left(8-10\gamma_3^2+3\gamma_3^4\right)\gamma_3 c_i c_j \\ &-2a_s\left(4-2\gamma_3-3\gamma_3^2+\gamma_3^3\right)\left(\left(4-3\gamma_3^2\right)c_j + \left(\gamma_3^2-2\right)\gamma_3 c_i\right) \\ &+\left(\gamma_3^2-2\right)^2\left(\gamma_3^2 c_i^2 + 16\left(\gamma_3^2-1\right)I_j\right) + \left(\left(4-3\gamma_3^2\right)c_j\right)^2.\end{aligned}$$

Appendix C: The Proof for standard findings and propositions

The proof for Standard Finding 1

The difference of profits in the first stage between two firms ($\pi_{c,i}^{1}*$ - $\pi_{c,j}^{1}*$) is $\frac{(2a_c - c_{c,i} - c_{c,j})(c_{c,i} - c_{c,j})}{\gamma_1^2 - 4}$. The denominatior is a negative value since 0 < γ_1 < 1 and the first term of the nominator is a positive value since $a_c > c_{c,i}$ and $a_c > c_{c,j}$. If $c_{c,i}$ is greater than $c_{c,j}$, $\pi_{c,i}^{1}*$ - $\pi_{c,j}^{1}*$ will be less than 0. This means that a firm that has a higher cost also has a lower profit. Moreover, γ_1 has no effect on a sign of $\pi_{c,i}^{1}*$ - $\pi_{c,j}^{1}*$, but the amount of a difference in profits.

The proof for Standard Finding 2

When $\gamma_2^c = \gamma_2^s$, and $a_s = a_c$, $\pi_{s,i}^{2}*$ - $\pi_{c,j}^{2}*$ is $\frac{c_{s,i}\left(c_{s,i}(y^2-1) - 2a_s(y-1)\right)}{\left(\gamma_2^c\right)^2 - 4}$ which equals to $\frac{c_{s,i}(y-1)\left(c_{s,i}(y+1) - 2a_s\right)}{\left(\gamma_2^c\right)^2 - 4}$. The denominater is a negative value since $0 < \gamma_2^c < 1$. The numerater is a positive value since $0 < y < 1$ and $c_{s,i} < a_s$. Thus, $\pi_{s,i}^{2}*$ - $\pi_{c,j}^{2}*$ is less than zero.

The proof for Proposition 1

$$\pi_{s,i}^{2}* - \pi_{c,j}^{2}* = \frac{-\left(c_{s,i}\left(\left(\gamma_2^c\right)^2 x + \gamma_2^c xy - 2\right) - a_s\left(\left(\gamma_2^c\right)^2 x + \gamma_2^c xz - 2\right)\right)^2}{\left(\left(\gamma_2^c\right)^2 x - 4\right)^2\left(\left(\gamma_2^c\right)^2 x - 1\right)} + \frac{\left(c_{s,i}\left(\left(\gamma_2^c\right)^2 xy + \gamma_2^c - 2y\right) - a_s\left(\left(\gamma_2^c\right)^2 xz + \gamma_2^c - 2z\right)\right)^2}{\left(\left(\gamma_2^c\right)^2 x - 4\right)^2\left(\left(\gamma_2^c\right)^2 x - 1\right)}.$$

The first term is a positive value while the second term is a negative value since $0 < \gamma_2^c < 1$ and $0 < x < 1$. $\pi_{s,i}^{2}* - \pi_{c,j}^{2}*$ will be greater than zero when the absolute value of the first term is greater than the absolute value of the seceond term; that is when the conditions in Proposition 1 are satisfied.

The proof for Standard Finding 3

$\pi_{s,i}^{3}*$ - $\pi_{s,j}^{3}*$ = $\frac{(a_s - c_{s,j})^2(3\gamma_3^{2} + \gamma_3 - 4)\gamma_3^{3}}{16(\gamma_3 + 1)(\gamma_3^{2} - 2)^2}$. The denominater is a positive value; while the numerater is a negative value since $(3\gamma_3^{2} + \gamma_3 - 4)$ is less than zero.

The proof for Proposition 2

$\pi_{s,i}{}^{2}*-\pi_{c,i}{}^{1}* = (a_s - c_{s,i})^2\left(\frac{(\gamma_2^c - 1)z^2}{(\gamma_2^c - 2)^2(\gamma_2^c + 1)} - \frac{(\gamma_2^c(\gamma_2^c x + xz) - 2)^2}{((\gamma_2^c)^2 x - 4)^2((\gamma_2^c)^2 x - 1)}\right)$. The first term is a positive value. The second term is also a positive value since $\left|\frac{(\gamma_2^c(\gamma_2^c x + xz) - 2)^2}{((\gamma_2^c)^2 x - 4)^2((\gamma_2^c)^2 x - 1)}\right| > \left|\frac{(\gamma_2^c - 1)z^2}{(\gamma_2^c - 2)^2(\gamma_2^c + 1)}\right|$. Therefore, $\pi_{s,i}{}^{2}*-\pi_{c,i}{}^{1}*$ is greater than zero.

The proof for Proposition 3

Given that $\frac{c_{c,i}}{c_{s,i}} = \frac{c_{c,j}}{c_{s,j}} = \frac{a_c}{a_s}$, and $\gamma_1 = \gamma_3$.

$$\pi_{s,i}{}^{3}*-\pi_{c,i}{}^{1}* = \frac{\left(c_{s,j}\gamma_3 + c_{s,i}(\gamma_3{}^2 - 2) - a_s(\gamma_3{}^2 + \gamma_3 - 2)\right)^2}{8\left(\gamma_3{}^2 - 4\right)^2\left(\gamma_3{}^4 - 3\gamma_3{}^2 + 2\right)}$$

$\times\left(\gamma_3{}^4 + 8\gamma_3{}^2(z^2 - 1) - 16(z^2 - 1)\right)$. Simce both terms are positive values, $\pi_{s,i}^{*\,3} - \pi_{c,i}^{*\,1}$ is greater than zero.

Given that $\frac{c_{c,i}}{c_{s,i}} = \frac{c_{c,j}}{c_{s,j}} = \frac{a_c}{a_s}$, $c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$.

$\pi_{s,i}{}^{3}*-\pi_{c,i}{}^{1}* = \frac{1}{8}\left(a_s - c_{s,j}\right)^2\left(\frac{(\gamma_1 w - 1)(\gamma_1 w + 2)^2}{\gamma_1{}^3 w^3 + \gamma_1{}^2 w^2 - 2\gamma_1 w - 2} + \frac{8(\gamma_1 - 1)z^2}{(\gamma_1 - 2)^2(\gamma_1 + 1)}\right)$. The first term is a positive value and the second term is a positive value since $\left|\frac{(\gamma_1 w - 1)(\gamma_1 w + 2)^2}{\gamma_1{}^3 w^3 + \gamma_1{}^2 w^2 - 2\gamma_1 w - 2}\right|$ is greater than $\left|\frac{8(\gamma_1 - 1)z^2}{(\gamma_1 - 2)^2(\gamma_1 + 1)}\right|$.

The proof for Proposition 4

$$\pi_{s,j}{}^{3}* - \pi_{c,j}{}^{2}* = \frac{\left(a_c - c_{c,j}\right)^2}{16(\left(\gamma_2^s\right)^2 - 1)z^2}$$

$\times\left(-\frac{(\left(\gamma_2^s\right)^3 - 3\left(\gamma_2^s\right)^2 - 2\gamma_2^s + 4)^2}{(\left(\gamma_2^s\right)^2 - 2)^2} + \frac{16(\left(\gamma_2^s\right)^2 y + \gamma_2^s - 2y)^2}{(\left(\gamma_2^s\right)^2 - 4)^2}\right)$. The first term is a negative value since $0 < \gamma_2^c < 1$. The second term will be a negative value if $\frac{(\left(\gamma_2^s\right)^3 - 3\left(\gamma_2^s\right)^2 - 2\gamma_2^s + 4)^2}{(\left(\gamma_2^s\right)^2 - 2)^2}$ is greater than $\frac{16(\left(\gamma_2^s\right)^2 y + \gamma_2^s - 2y)^2}{(\left(\gamma_2^s\right)^2 - 4)^2}$. The conditions to make $\frac{(\left(\gamma_2^s\right)^3 - 3\left(\gamma_2^s\right)^2 - 2\gamma_2^s + 4)^2}{(\left(\gamma_2^s\right)^2 - 2)^2}$ to be greater than $\frac{16(\left(\gamma_2^s\right)^2 y + \gamma_2^s - 2y)^2}{(\left(\gamma_2^s\right)^2 - 4)^2}$ are shown in the Proposition 4.

The proof for Proposition 5

$$\pi_{s,i}{}^{2}*-\pi_{c,i}{}^{1}* = \frac{\left(\left(\gamma_2^c\right)^2+\gamma_2^c-2\right)^2\left(c_{s,i}y-a_sz\right)^2}{\left(\left(\gamma_2^c\right)^2-4\right)^2\left(\left(\gamma_2^c\right)^2-1\right)}$$

$$-\frac{\left(c_{s,i}\left(\left(\gamma_2^c\right)^2+\gamma_2^c y-2\right)-a_s\left(\left(\gamma_2^c\right)^2+\gamma_2^c z-2\right)\right)^2}{\left(\left(\gamma_2^c\right)^2-4\right)^2\left(\left(\gamma_2^c\right)^2-1\right)}$$. The first term,

$$\frac{\left(\left(\gamma_2^c\right)^2+\gamma_2^c-2\right)^2\left(c_{s,i}y-a_sz\right)^2}{\left(\left(\gamma_2^c\right)^2-4\right)^2\left(\left(\gamma_2^c\right)^2-1\right)}$$, is a negative value since $0<\gamma_2^c<1$. The second term,

$$-\frac{\left(c_{s,i}\left(\left(\gamma_2^c\right)^2+\gamma_2^c y-2\right)-a_s\left(\left(\gamma_2^c\right)^2+\gamma_2^c z-2\right)\right)^2}{\left(\left(\gamma_2^c\right)^2-4\right)^2\left(\left(\gamma_2^c\right)^2-1\right)}$$, is also a positive value since $0<\gamma_2^c<1$.

The second term is greater than the first term, or the leader firm will get a higher profit when launch a new sustainable product if the conditions in Proposition 5 are satisfied.

The proof for Proposition 6

$$\pi_{s,i}{}^{2}*-\pi_{c,i}{}^{1}* = \frac{c_{s,i}\left(\left(\gamma_2^c\right)^2-2\right)(y-1)}{\left(\left(\gamma_2^c\right)^2-4\right)^2\left(\left(\gamma_2^c\right)^2-1\right)}$$

$$\times\left(-2a_s\left(\left(\gamma_2^c\right)^2+\gamma_2^c-2\right)+c_{s,i}\left(2\gamma_2^c y-2(y+1)+\left(\gamma_2^c\right)^2(y+1)\right)\right).$$

The first term is a negative value since $0<\gamma_2^c<1$ and $0<y<1$. The second term will be negative when the conditions in Proposition 6 are satisfied.

The proof for Standard Finding 4

From (7), $p_{s,i}=\left[\theta a_s+(1-\theta)a_c\right]-q_{s,i}-\gamma_2^s q_{c,j}$. Thus, $p_{s,i}=\left[\theta a_c+(1-\theta)a_c\right]-q_{s,i}-\gamma_2^s q_{c,j}$ $=a_c-q_{s,i}-\gamma_2^s q_{c,j}$.

The proof for Proposition 7

$$\pi_{s,i}{}^{2}* - \pi_{c,i}{}^{1}* = \frac{(\gamma_1-1)(c_{s,i}y-a_sz)^2}{(\gamma_1-2)^2(\gamma_1+1)}$$

$$- \frac{\left(c_{s,i}\left(\left(\gamma_2^c\right)^2+\gamma_2^c y-2\right)+a_s\left(z\left(2-\gamma_2^c+\left(\gamma_2^c\right)^2(\theta-1)-2\theta\right)-\left(\left(\gamma_2^c\right)^2-2\right)\theta\right)\right)^2}{(\left(\gamma_2^c\right)^2-4)^2(\left(\gamma_2^c\right)^2-1)}.$$

The first is a negative value; while, the second term is a positive value since $0<\gamma_1<1$.

Thus $\pi_{s,i}{}^{2}*$ - $\pi_{c,i}{}^{1}*$ will be a positive value when $\left|\frac{(\gamma_1-1)(c_{s,i}y-a_sz)^2}{(\gamma_1-2)^2(\gamma_1+1)}\right|$ is less than

$$\left|\frac{\left(c_{s,i}\left(\left(\gamma_2^c\right)^2+\gamma_2^c y-2\right)+a_s\left(z\left(2-\gamma_2^c+\left(\gamma_2^c\right)^2(\theta-1)-2\theta\right)-\left(\left(\gamma_2^c\right)^2-2\right)\theta\right)\right)^2}{(\left(\gamma_2^c\right)^2-4)^2(\left(\gamma_2^c\right)^2-1)}\right|$$, or when the conditons in Proposition 7 are satisfied.

The proof for Proposition 8

$\pi_{s,i}{}^2* - \pi_{c,j}{}^2* = \frac{(z-1)(c_{s,i}(z+1)+a_s(z(\theta-2)-\theta))(c_{s,i}-a_s\theta)}{\left(\gamma_2^c\right)^2-4}$. The denominater is a negative value since $0<\gamma_2^c<1$. The numerater is a positive value when $(c_{s,i}(z+1)+a_s(z(\theta-2)-\theta))(c_{s,i}-a_s\theta)$ is a positive value. That is $\pi_{s,i}{}^2* - \pi_{c,j}{}^2*$ is greater than zero when the conditions in the Proposition 8 are satisfied.

The proof for Proposition 9

$\pi_{s,i}{}^2* - \pi_{c,j}{}^2* = \frac{1}{(x-4)^2(x-1)}\ [-\left(c_{s,i}(xz+x-2)+a_s\left(z(2+x(\theta-2)-2\theta)-(x-2)\theta\right)\right)^2$ $+\left(c_{s,i}(1+(x-2)z)+a_s(-\theta+z(\theta-x+1))\right)^2]$. The first term is a negative value. The second term will be a negative value when $\left(c_{s,i}(xz+x-2)+a_s\left(z(2+x(\theta-2)-2\theta)-(x-2)\theta\right)\right)^2$ is greater than $\left(c_{s,i}(1+(x-2)z)+a_s(-\theta+z(\theta-x+1))\right)^2$, or when the conditions in Proposition 9 are satisfied.

The proof for Proposition 10

$\pi_{s,i}{}^2* - \pi_{c,j}{}^2* = -\frac{1}{\left(z-4\right)^2}\ [(z-1)[c_{s,i}{}^2(6z+3)+2a_s c_{s,i}(z^2(\theta-1)-3\theta-z(5+\theta))$ $+a_s{}^2(2z(5-2\theta)\theta+3\theta^2+z^2(\theta^2-4\theta+3))]]$. The first term is a negative value. The second term will be a negative value when $c_{s,i}{}^2(6z+3)$ $+a_s{}^2(2z(5-2\theta)\theta+3\theta^2+z^2(\theta^2-4\theta+3))$ is greater than $2a_s c_{s,i}(z^2(\theta-1)-3\theta-z(5+\theta))$, or when the condition in Proposition 10 are satisfied.