SUSTAINABLE ATTRIBUTE VALUATION AND MANUFACTURER'S SUSTAINABLE PRODUCT LAUNCH DECISION MAKING: AN EGG INDUSTRY CASE

By

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ABSTRACT

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Sustainability is one of the most important issues facing all agents along the global food supply chain. Consumers have an increased awareness about environmental problems, animal welfare, and communities, which has led to greater demand for sustainable food and drink products. This demand induces retailers and manufacturers to produce and market more sustainable products. Some manufacturers are reluctant to implement sustainable practices, or develop and market new sustainable food products due to a lack of information about price premiums of sustainable attributes and a systematic decision model.

This dissertation aims to: analyze price premiums of sustainable attributes; construct firms' decision making model; determine under which conditions firms launch sustainable products; and determine which conditions encourage a firm to be a leader who launches a sustainable product before others. Hedonic analysis is used to find the price premiums of sustainable products while game theory, comparative statics, and simulation are utilized to construct the firms' decision making regarding under which conditions firms launch sustainable products, and which conditions encourage a firm to be a leader.

The U.S. egg industry was selected to estimate the price premiums of sustainable attributes, and simulate and test the firms' decision making model. According to the study the welfare-managed attribute (free-range or cage-free attribute) is significantly positive. That is, a

welfare-managed egg has a price premium over a conventional egg equal to 3.57 cents while the recyclable attribute (paper-pulp packaging attribute) is insignificant.

The follower's decision making to launch a sustainable product is the main contribution of the game theory study. That is, the follower decides to produce and market a "me-too" sustainable product when consumers realize the difference between the conventional and sustainable product and are willing to pay more for the sustainable product. If not, the costs of both types have to be sufficiently close to induce the follower to launch the sustainable product. The leader decides to launch a sustainable product when the relative maximum willingness to pay for the sustainable product over the conventional product is greater than or equal to its relative cost or when the maximum willingness to pay for the sustainable product is sufficiently higher than the cost of the sustainable product.

The main factors that encourage a firm to be a leader are: 1) a cost advantage in producing a sustainable product, 2) a cost disadvantage in producing a conventional product, and 3) a firms relative cost being lower than the consumers' willingness to pay for a sustainable product. The U.S. egg industry simulation results show that both leader and follower firms should market the sustainable eggs to achieve higher profits. The simulation results agree with what is observed in terms of the growth in the free-range and cage-free eggs market in the U.S.

For my parents, Poonsuk and Pojjanee Tonganupong, and my husband

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Nevertheless all deficiencies and ambiguities in this dissertation are solely my responsibility.

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CHAPTER 1: INTRODUCTION

During the past few years, there has been an important trend observed along the food supply chain, a "sustainable food trend." This dissertation is about the "sustainable food product" trend. More than 13,000 sustainable food and drink products were launched in the market from 2005-2010 (Browne 2010). Several key factors have supported the expansion of launching sustainable products. First, consumers are becoming more aware of environmental problems and have increasingly demanded manufacturers to produce food products in a more environmentally friendly way (Oberholtzer, Greene, and Lopez 2006). Eighty-four percent of the U.S. consumers interviewed indicated that they sometimes or regularly purchase sustainable foods and drinks, especially those with "buy local" or "recyclable packaging" claims (Browne 2010). Moreover, consumers' food safety scares in last year (i.e., the impacts of the Gulf Coast oil spill on seafood, and the impacts of egg recall from salmonella poisoning) may have increased consumers' demand for sustainable food and drink products. This implies more market opportunities for sustainable products.

Second, retailers acknowledge that there is an increase in consumers' demand for sustainable products and they must improve their strategies to respond to those demands. Retailers are using their market power to encourage manufacturers to supply more sustainable products. For example, Walmart, the world largest retailer, is currently creating a "Sustainability Index" (targeting 2014 completion) that can measure the environmental performance of suppliers, and improve efficiency by reducing costs and waste (Browne 2010). This sustainability program is expected to influence not only other retailers but also manufacturers.

Third, manufacturers have gradually repositioned their strategies to be more sustainable. The Accenture and United Nation Global Compact (UNGC) interviewed 766 CEOs around the world in 2010 and found that manufacturers invest in sustainability for three reasons: brand, trust and reputation (Broder 2010). Hence, launching sustainable products can be a public relation strategy of the firms to improve their image and goodwill. Manufacturers also invest in sustainable practices to reduce production costs and increase their competitiveness. The Accenture and UNGC study also showed that CEOs realize that incorporating sustainability practices can be a source of cost efficiency and revenue growth even during an economic downturn (Broder 2010).

Lastly, in addition to the agents along the food supply chain, third party certifiers and government agencies are also concerned about sustainability. Several standards and regulations were implemented to support environmental and sustainable policies. For example, dolphin safe and Marine Stewardship Council environmental standard for sustainable fishing are two sustainable seafood product certifications. Governments have also announced regulations to control pollution emissions from factories. These regulations are perceived to be increasing sustainable production, which includes animal welfare policies in Europe and in California (Proposition 2 of 2008)[1].

Some food manufacturers are reluctant to implement sustainable practices, or develop and market new sustainable food products, although sustainability is at the forefront of most food manufacturer CEOs' minds. Part of their reluctance is due to a lack of information about price premiums for sustainable attributes and a systematic decision making model.

[1] Proposition 2 intends to improve animal production practices, such as, allowing animals to run around freely, lie down, stand up, and fully extend their limbs outside their cage. This proposition will become operative on January 1, 2015 (2008).

The objectives of this dissertation are to: analyze price premiums of sustainable attributes; construct food firms' innovation decision making model; explore under which conditions firms launch sustainable products; and determine which conditions encourage a firm to be a leader by launching a sustainable product first. Hedonic analysis is used to find the price premiums of sustainable products while game theory, comparative static, and simulation are employed to construct the firms' decision making regarding under which conditions firms launch sustainable products, and which conditions encourage a firm to be a leader.

The U.S. egg industry was selected to estimate the price premiums of sustainable attributes, and simulate and test the firms' decision making model. There are several reasons why the U.S. egg industry is appropriate to study. First, eggs are an important commodity, which is globally one of the cheapest sources of protein, and consumers make frequent purchases. Second, eggs are not complicated food products, and consumers can easily understand the marketing message from manufacturers about their sustainable attributes. Third, the new legislation concerning animal welfare in egg production has influenced many egg manufacturers to market sustainable eggs. Lastly, the cost and price data for conventional and sustainable eggs are available.

The dissertation consists of an introduction (chapter 1), two independent papers (chapters 2 and 3) and a conclusion (chapter 4). The introduction includes the motivations and the reasons why the U.S. egg industry was chosen. The core of the dissertation is composed of two individual papers entitled: hedonic analysis of sustainable food products, and food manufacturers' sustainable product launch strategy: game theory approach. The conclusion discusses the overall findings from the dissertation.

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CHAPTER 2: HEDONIC ANALYSIS OF SUSTAINABLE FOOD PRODUCTS

2.1 Introduction

Sustainability is one of the most important issues facing the global food supply chain. There are 9,450 new food and beverage products claimed to be ethically or environmentally produced[1] globally from February 2009 to January 2010 (Mintel 2010). This represents almost 10% of all new food and beverage products (Mintel 2010). This nebulous concept has the ability to change international trade patterns, make firms invest millions of dollars to change suppliers (i.e. McDonalds' sustainable supply chain (2010a), and change product components to minimize damage to brand name image).

There are four critical reasons why analyzes need to be conducted on food manufacturers and retailers concerning sustainability. First, from the CIES survey[2] of the largest food supermarket retailers globally, corporate social responsibility emphasizing sustainability was the top issue that CEOs were concerned about in 2008 ("Top of Mind Survey" 2008). In the previous years, sustainability was ranked 5th in 2007 and 11th in 2006. One of the main reasons supermarket chains are concerned is that NGOs and customers are putting more pressure on them to source "Sustainably," and are being graded by certain NGOs, i.e., Greenpeace (2009a). CEOs realize the importance of sustainability to the competitiveness of their businesses, but they are not certain of which investments to make in order to strengthen their brands.

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[1] Ethical categories include ethical-animal, ethical charity, and ethical-human categories. Moreover, Environmental categories include environmentally-friendly package, and environmentally-friendly product categories.

[2] The CIES survey is a survey of the Consumer Goods Forum which is an independent global parity-based Consumer Goods network. (www.ciesnet.com)

Second, companies are trying to improve their supply chain by reducing costs and carbon use simultaneously. The reduction in carbon emissions not only reduces the costs to the firm, but may also promote the firm's image and goodwill. For instance, in April 2008, Tesco announced the launch of "The Carbon Reduction Label," which focuses on energy usage and adopting the concept of "sustainability" policies to its retail center and its own private brand products ("Tesco and Carbon Trust Join Forces to Drive Forward Carbon Labeling" 2008). Promoting energy saving is popular, for example, many companies began to use wind energy, and reclaim cooking oil and solar energy to substitute gas in their production processes (Weil 2008).

Third, consumers are becoming more aware of environmental problems and are interested in consuming products that are considered to be sustainably produced. This has led to a growing number of green consumers[3]. In the United States, the growth of consumers who are always or almost always green consumers increased from 12% in 2006 to 36% in 2007 (O'Donnell 2008). This implies more market opportunities for sustainable products since consumers are willing to pay for high quality products as well as products that help improve the environment.

Lastly, several standards and regulations were implemented to support environmental and sustainable policies. The examples of voluntary standards related to the environment are the ISO 14000 series. Also, there are several certifications for sustainable seafood products, such as, Marine Stewardship Council's fishery certification program and seafood eco-label, and dolphin safe label. Governments have announced regulations to control pollution emissions from factories as well. These regulations are perceived to be increasing sustainable production, which includes animal welfare policies in Europe and in California (Proposition 2 of 2008).

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[3] A green consumer is a person who is concerned about environmental or social issues constantly when deciding on purchasing products (Peattie and Charter 1992).

Due to the pressure from retailers, consumers, legislation and competition, more sustainable food products are being launched (i.e. dolphin safe tuna products, cereal with recyclable packaging, and free-range and other environmentally-friendly eggs). This study analyzes the value of sustainable attributes for fresh eggs by using hedonic price analysis and survey data of fresh egg prices in five city areas along the Eastern coast of the United States.

Sustainability has been defined by various organizations and companies and has led to a brand definition. Therefore, we will focus only on why two attributes in this study represent sustainable attributes. The first attribute is a welfare-managed attribute. In our study, welfare-managed eggs include free-range eggs and free-cage eggs[4]. To understand why the welfare-managed attribute represents a sustainable attribute, the concept of sustainable agriculture is introduced. According to the USDA, sustainable agriculture is defined as an integrated system of plant and animal production practices that has a site-specific application that will occur over the long term (United States Department of Agriculture 2007). Also, there are many approaches to define "animal welfare". A well-known definition is that 'welfare' is the state of a being in relation to its environment (Broom 1991; Blandford et al. 2002). The conventional process for raised hens is a battery cage system which provides space of 67 to 86 inches per bird (2010b); consequently, hens in battery cages do not have enough space for free movement. Welfare-managed systems including free range/cage free systems can improve animal welfare by allowing them to extend their limbs freely. Hence, the welfare-managed attribute represents one of the sustainable attributes as stated in Bennett (1998) "Consumers who are concerned about

[4] 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. Free-cage eggs are from hens that live in indoor floor facilities, but do not necessarily have access to the outdoors.

animal welfare prefer and are willing to pay more for methods of animal husbandry that allow hens to roam freely instead of being in cages".

The second attribute representing a sustainable attribute is paper-pulp packaging since sustainability also includes an environmental dimension of recycling. For example, Spartan Stores and Wegmans changed their packaging of their store-brand eggs to be new recyclable and biodegradable molded fiber packaging to replace Styrofoam cartons that are not biodegradable (2009b; Wegmans 2010). Therefore, paper-pulp packaging, which is recyclable and/or made from recycled material, is considered to be one of the sustainability attributes in this study.

2.2 Objectives

This study aims to determine price premiums for sustainable attributes of fresh eggs by using hedonic analysis. The sustainable attributes defined here include the free-range/cage-free attribute and recyclable attribute for packaging which is paper-pulp packaging. Furthermore, we will focus on the interaction between organic and sustainable attributes; that is, whether sustainable attributes of eggs have a higher value when eggs are organic.

This work is unique for several reasons. First, most of the literature focuses on analyzing the value of organic attributes more than sustainable attributes. Examples of papers that analyzed the price premiums of organic products are: Gil, Gracia, and Sanchez 2000; Canavari et al. 2002; Soler, Gil, and Sánchez 2002; Ara 2003; Wang and Sun; Batte et al. 2007; Griffith and Nesheim 2008. Second, most of the literature concerning price premiums for sustainable attributes used the contingent valuation approach (Loureiro, McCluskey, and Mittelhammer 2001; Loureiro and Hine 2002; Loureiro, McCluskey, and Mittelhammer 2002). Third, the unique data set was collected from five East coast U.S. cities and has not been analyzed for sustainable attributes for fresh eggs and the economic implications thereof. Moreover, there is no literature on price premiums for sustainable attributes of eggs in the U.S. Most egg literature studied specialty egg characteristics and the overall U.S. egg industry (Patterson et al. 2001; Knudson 2004; Oberholtzer, Greene, and Lopez 2006; Patterson et al. 2008). Lastly, recent studies suggest that eco-labels, an example of a sustainable attribute, should be added to complement other valued product attributes such as organic attribute in order to attract more consumer purchases (Johnston et al. 2001; Arquitt and Cornwell 2007). Hence, this work also aims to test the hypothesis that multi-attribute eggs such as sustainable attributes and organic eggs are more valued.

2.3 Egg Industry

The egg industry is a great industry to better understand consumer evaluations of sustainable attributes of food products for several reasons. First, the fresh egg industry in the U.S. is a huge and important industry which had a market size equal to $ 5.73 billion in 2010 (Patterson 2011). Second, quality survey data for egg prices and their attributes in key eastern U.S. cities are available. Third, eggs are not complicated food products and consumers can easily understand the marketing messages, and the sustainable attributes are easily included into our model. Fourth, organic eggs and free-range/cage-free are easily understood and well known attributes among egg consumers[5]. Lastly, due to the vote for proposition 2 in California in 2008,

[5] Organic regulations require outdoor access for birds (Oberholtzer, Greene, and Lopez 2006); therefore, organic eggs are a subset of free-range/cage-free eggs. However, we define organic and welfare-managed attributes separately because we are interested in the interaction between these two attributes. Egg manufactures sometimes label their organic eggs as cage-free eggs; while, others do not. Consumers might be confused whether organic eggs are welfare-managed eggs or not. The study is based on consumers' perception; therefore, we identify the attributes of each observation based on information on the label.

the industry recognizes the importance of free range/cage free in the future to their market and the potential for this movement to spread across America.

There are two main segments for the egg market which are fresh shell eggs, and egg substitutes[6]. In 2010, fresh eggs had a market share equal to 93.6%, while egg substitutes had a market share of only 6.4% (Patterson 2011). Hence, this study focuses only on the fresh egg market. There are two types of fresh eggs, which are regular eggs and specialty eggs. Examples of specialty eggs are free-range/cage-free eggs, organic eggs, eggs fortified with Omega-3 fatty acids, low-cholesterol eggs, and vegetarian-fed eggs.

Store brands[7] dominate national brands and regional brands in the fresh egg market. In 2010, store brands had a market share equal to 66.8%, while Eggland's Best, Cal-Maine Foods, Rose Acre Farms Inc., and others had market shares equal to 9.9%, 2.6%, 2.0%, and 18.8%, respectively (Patterson 2011).

2.4 Methodology

Lancaster (1966) stated that a good does not give utility directly to a consumer, but it possesses characteristics or attributes which give utility to the consumer. Hedonic prices are defined as the implicit prices of attributes embodied in each good (Rosen 1974). Economic agents can determine hedonic prices of attributes by observing prices of differentiated products and specific amounts of attributes related to them (Rosen 1974). Examples of attributes are brand, packaging, color, taste, etc. If a good has a number of characteristics or attributes, $\boldsymbol{z}$, equal

[6] Breaker or breaker plant category is not in the scope of this study because our study focuses on consumer goods. Breakers are industrial goods which are not available in supermarkets but are used in restaurants, hospitals, schools, and other food service (United States Department of Agriculture 2010).

[7] Store brand is interchangeable with private label.

to k, $z = (z_1, z_2, ..., z_k)$, the price for a good is determined by a set of attributes or vector $\boldsymbol{z}$, that is $price(z) = f(z_1, z_2, ..., z_k)$. Hedonic pricing analysis and contingent valuation are the two main approaches used to calculate price premiums of unique attributes. The contingent valuation requires consumer survey data to determine if the premium of each attribute has value. Numerous papers have utilized this approach to address price premiums for food product attributes (Wessells, Johnston, and Donath 1999; Gil, Gracia, and Sanchez 2000; Loureiro, McCluskey, and Mittelhammer 2001; Canavari et al. 2002; Loureiro and Hine 2002; Loureiro, McCluskey, and Mittelhammer 2002; Ara 2003; Cranfield and Magnusson 2003; Batte et al. 2007). The weakness of this approach is that it only reflects consumers' intentions but not their actual actions in terms of purchasing behavior. Moreover, it is possible that the survey might create a bias in the sense that consumers might over-estimate their willingness to pay for sustainable products, which leads to the problem of over-estimating the price premium for sustainable attributes. Several papers analyzed or have referred to the biases of the contingent valuation approach (Diamond and Hausman 1994; Blumenschein et al. 1998; Aadland and Caplan 2003; Ajzen, Brown, and Carvajal 2004; Blumenschein et al. 2008).

Historically, hedonic analysis primarily has used scanner data[8] or privately collected secondary data. Several authors used hedonic analysis for measuring a price premium of differentiated food product (wine, coffee, etc.) attributes (Nimon and Beghin 1999; Combris, Lecocq, and Visser 2000; Donnet, Weatherspoon, and Hoehn 2008; Griffith and Nesheim 2008). The data for this study was collected from retailers who are concerned about consumer demand

[8] Scanner data are "retail purchase information (such as price, brand, product size, amount purchased) gathered at the point of purchase by an electronic device that reads a coded ticket on the product through the use of an electronic reader over which the product passes." (www. Answer.com)

and maximize their profits by determining the optimal attributes, prices and quantities to offer (Steiner 2004; Karipidis et al. 2005). The partial derivative of the hedonic price function with respect to a particular attribute is an implicit or shadow price at equilibrium that reflects both, the maximum price consumers are willing to pay for an additional attribute, and the minimum price for which suppliers are willing to sell according to their costs (Sanjuán-López, Resano-Ezcaray, and Camarena-Gómez 2009). Moreover, consumers decide whether they should accept the price and purchase the eggs or not based on the retailers' offered price. Therefore, the price and attributes collected from retailers can be used to find the value of attributes by using hedonic analysis without ignoring the consumer side.

There are two advantages of using hedonic price analysis over contingent valuation. First, the hedonic price approach does not require joint consumption of goods within a group. Therefore, we can estimate the inverse demand of specific goods individually rather than modeling the whole system of demand and supply. Second, according to Butler (1982), since all estimates of hedonic price models are to some extent misspecified, models that use a small number of key variables generally suffice. Butler suggested that only those attributes that are costly to produce and yield utility are to be considered in the regression equation. Therefore, we need to use less attributes in our model so that we reduce the misspecification problem and increase the degrees of freedom.

Assume that an egg has k attributes plus sustainable attributes, organic attribute, and a sustainable and organic attribute. The egg price then depends on its attributes (Rosen 1974) defined as follows:

$price(\boldsymbol{x})$ = f ($x_1, x_2,..., x_k$, sustainable attribute, organic attribute, sustainable and organic attribute), where $price(\boldsymbol{x})$ represents the price of an egg, and vector $\boldsymbol{x}$ represents attributes of the egg. Specifically, the model in our study is specified as the following:

$$\begin{aligned} priceperegg = \; & \beta_0 + \beta_1 o + \beta_2 wm + \beta_3 owm + \beta_4 vd + \beta_5 ne \\ & + \beta_6 regional + \beta_7 national + \beta_8 brown + \beta_9 AA \\ & + \beta_{10} plastic + \beta_{11} paper + \beta_{12} large + \beta_{13} extralarge + \beta_{14} jumbo \\ & + \beta_{15} acme + \beta_{16} giant + \beta_{17} pathmark + \beta_{18} safeway + \beta_{19} shopper \\ & + \beta_{20} shaws + \beta_{21} shoprite + \beta_{22} superfresh + \beta_{23} stopandshop \\ & + \beta_{24} wegmans + \beta_{25} weis \\ & + \beta_{26} shelllabel + \beta_{27} eggage + \beta_{28} unitsize + \varepsilon , \end{aligned}$$

where β's represent the coefficients for the product attributes and ε is the error term. The definitions, minimums, maximums, and means of each variable are depicted in table 2.1. In this model, the base variables for each category of dummy variable attributes are dropped in order to prevent perfect multicollinearity.

2.5 Data and Variable Description

The data used in our analysis are survey data of fresh egg prices and their attributes[9]. The data have 207 usable observations and were collected from retailers in five east coast cities (Baltimore, MD; Boston, MA; New York, NY; Philadelphia, PA; and Washington DC) in 2007. The data come from retail supermarkets (ACME, Giant, Pathmark, Safeway, Shoppers Food Warehouse, Shaw's, ShopRite, Super Fresh, Stop and Shop, Walmart, Wegmans, and Weis) in each of these cities.

[9] We would like to thank Dr. Paul H. Patterson, from the Poultry Science Department at Penn State University for providing us with the data.

From table 2.1 (see appendix A), the first group of attributes is a group of specialty characteristics of the eggs which are regular, organic, vegetarian-fed, welfare-managed including free-range and free-cage, nutritionally enhanced[10], and a stacked attribute, organic and welfare-managed. The second group is categorized by brand. To preserve the degrees of freedom, we separate egg brands into three groups which are national, regional and store brands. The third group is categorized by colors which are white and brown. The fourth attribute is grouped by grades of eggs (grades A and AA), which reflect the quality and the freshness of the eggs, i.e., the firmness of the yolk, and the air cell in the egg. The fifth group is defined by packaging materials which are Styrofoam, paper pulp, and clear plastic. The sixth group is determined by egg sizes which are medium, large, extra large, and jumbo. The seventh group of attributes is determined by the retailers where consumers purchase eggs (ACME, Giant, Pathmark, Safeway, Shoppers Food Warehouse, Shaw's, ShopRite, Super Fresh, Stop and Shop, Walmart, Wegmans, and Weis). The eighth attribute is defined based on whether there is a label on the egg shell or not. The next variable is the age of the egg that is defined as the number of days from when an egg is laid until it is purchased at the store[11]. The last attribute is an egg unit which is the number of eggs per package.

[10] From our survey data, nutritionally-enhanced eggs are high-omega 3, high-vitamins, and low-cholesterol.

[11] Egg cartons with the USDA grade shield on them are regulated to display the "pack date" which is defined as the day that the eggs were washed, graded, and placed in the carton (F. S. and I. S. United States Department of Agriculture 2007). We get the information about the age of the egg by using the pack date and assuming that eggs are packed the same day as they are laid.

Credence Goods

The attributes can be categorized into three categories which are search, experience, and credence attributes (Caswell and Mojduszka 1996; Bureau, Marette, and Schiavina 1998; Loureiro, McCluskey, and Mittelhammer 2002; De Pelsmacker, Driesen, and Rayp 2005). Search attributes are those that consumers can observe immediately before purchase, i.e. color, size, and price. Experience attributes, such as taste, are attributes that consumers discover only after consumption. Credence attributes are attributes of which consumers can detect the quality neither before nor after buying the product. The ethical attribute, such as cage-free, is an example of a credence attribute. This leads to the problem of asymmetric information in the cage-free egg market.

Asymmetric information is addressed by manufacturers labeling their products; however, the credibility of manufactures is critical to getting price premiums and higher profits. Third Party Certification proof with high public trust can increase ethical label credibility (Loureiro, McCluskey, and Mittelhammer 2002; De Pelsmacker, Driesen, and Rayp 2005); however, there is no well-known certification for cage-free eggs in the U.S. market. Consequently, reputation of egg manufactures is the only signal for the cage-free attribute, and U.S. consumers might be still confused and reluctant to trust cage-free labels, which could lead to low cage-free eggs purchasing.

Egg Packaging

There are three types of material for egg packaging which are paper pulp, clear plastic, and Styrofoam. Paper-pulp packaging is claimed to be recyclable and made from recycled paper. Clear plastic and Styrofoam are technically plastics and recyclable. Clear plastic packaging for eggs is made from polyolefins and defined as code 1 (Polyethylene terephthalate: PET) recyclable symbol. Styrofoam packaging is made from polystyrene (PS) and defined code 6 for its recyclable symbol (Marsh and Bugusu 2007).

Even though all materials for egg packaging are recyclable, paper and paperboard have the highest recycle rate. In 2007, 54.5% of paper and paperboard was recovered for recycling; while, plastics including Styrofoam had a recycle rate equal to 6.8% (United States Environmental Protection Agency 2008). Moreover, some egg manufactures marketed their eggs by changing material for their packaging from Styrofoam to paper pulp and claimed that their new packaging was more environmentally-friendly. For example, Spartan Store and Wegmans changed their egg packaging from Styrofoam packaging to paper-pulp packaging and claimed that their packaging is more sustainable or more environmentally-friendly (2009b; Wegmans 2010). As a consequence, this study used paper-pulp packaging as its sustainable packaging attribute.

2.6 Results

Table 2.2 (see appendix A) presents hedonic prices of egg attributes from the estimation. The R-squared for the model shows that all egg attributes explain about 81.2% of the variation in the prices of eggs. The attributes that significantly affect the price of eggs are specialty characteristics, brands, grades, sizes, retailers (places where consumers buy eggs), and unit sizes. Signs of significant variables are as expected and the same as previous literature (Ness and Gerhardy 1994; Fearne and Lavelle 1996; Karipidis et al. 2005; Goddard et al. 2007) except the sign for the stacked variable attribute organic and welfare-managed (owm).

Most specialty characteristic coefficients which are organic attribute (o), welfare-managed attribute (wm), and nutritionally-enhanced attribute (ne) have positive values and are significant. Organic, welfare-managed, and nutritionally-enhanced eggs have price premiums over regular eggs equal to 16.50, 3.57, and 2.30 cents per egg, as shown in figure 2.1 respectively. This means that these attributes create value-added for the shell egg category. The coefficient for the vegetarian-fed attribute is a negative value, but not significant. Hence, it is ambiguous to conclude the value of the vegetarian-fed attribute.

The coefficient for the stacked variable attribute, organic and welfare-managed, equals -8.81 cents per egg and is significant. Therefore, an organic and welfare-managed egg has a premium over a regular egg equal to 11.26 cents which is less than the premium for an organic egg (11.26 = 16.50 + 3.57 – 8.81 cents representing the premium for organic, welfare-managed, and organic and welfare-managed attributes). The authors did not expect the negative sign for the stacked variable. We expected that welfare-managed eggs would get higher premiums when they are also marketed (labeled) as organic because consumers can easily associate the perceived animals health benefits and be willing to pay a premium for it. There are three hypotheses to explain this result. First, consumers might be confused about the definition of eggs with these attributes and hence not be willing to pay more for the stacked attributes. Second, it might be possibly related to retailers' strategies (Greenblum 2009)[12] to promote theirs store brands as sustainable brands; hence, offer promotions for the organic and welfare-managed products. Lastly, farmers might be able to share some production costs for the organic, free-range and/or free-cage methods; hence, the prices reflect supply and demand side effects. The prices of regular eggs and specialty eggs are compared in figure 2.1.

[12] Ms. Greenblum is a senior director of Nutrition Education, Egg Nutrition Center.

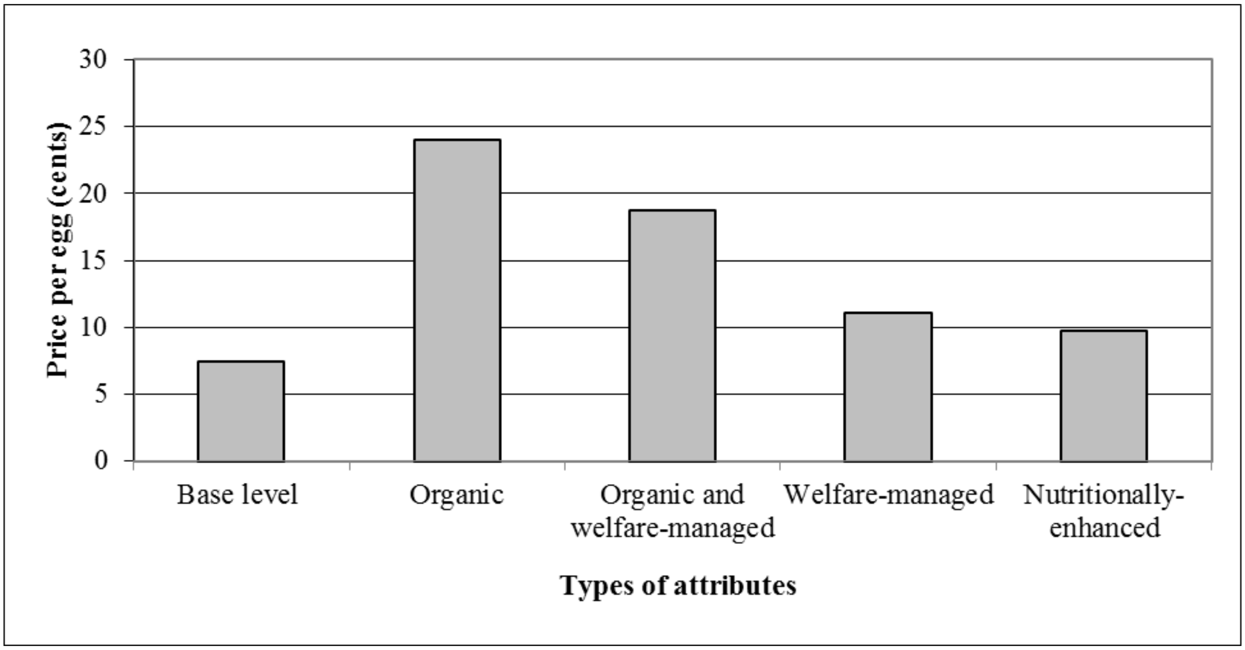

Figure 2.1 Prices of the base level and specialty eggs[13] (cents per egg)

National brand eggs and regional brand eggs have price premiums equal to 5.33 cents and 3.95 cents compared to store brand eggs. Prices of grade AA eggs are significantly higher than prices for grade A eggs. Its price premium equals to 3.28 cents. All coefficients of sizes are significant. That is the larger size egg has a higher price premium. The coefficient for unit size is negative and significant. Therefore, the price per egg is lower when consumers buy eggs in bigger packages. Eggs from almost all retailers[14] have significantly higher prices than the price

[13] Assuming that other attributes are the same, the base level egg for each category is defined as an egg with the following attributes: regular, store brand, white color, grade A, Styrofoam packaging, medium size, no shell label, egg age of 14 days, a dozen egg unit size, and Walmart is the base store. Specialty eggs have the same attributes as the base level eggs except they are not regular eggs.

[14] From table 2.2, these retailers are ACME, Giant, Pathmark, Safeway, Shoppers Food Warehouse, Shaw's, ShopRite, Super Fresh, Stop and Shop, Wegmans, and Weis.

of eggs from Walmart. Lastly, the coefficients of the rest of the variables which are various types of packaging, brown color, shell label and egg age are all insignificant.

2.7 Conclusion and Management Implications

We tested two attributes that we consider sustainable, welfare-managed, and paper-pulp packaging; only one was found to positively and significantly influence price. Welfare-managed eggs receive the price premium equals to 3.57 cents per egg as compared to regular egg. The attribute that has the greatest impact on price was the organic attribute which increase the price per egg by 16.50 cents. Interestingly, when organic and welfare-managed were combined the price premium was only 11.26 cents per egg. This implies that consumers are not willing to pay for both labeled attributes simultaneously, which has major implication for egg manufactures and retailers. In the short run, egg manufactures should maximize profit by offering and labeling either organic or welfare-managed eggs, and hence continue to segment the market until consumers perceive these attributes as being different.

Our results are ambiguous for the paper-pulp packaging attribute. Some egg manufacturers have claimed that their Styrofoam packaging and/or clear-plastic packaging are recyclable. A survey of consumers' perception about recyclable packaging might be helpful to answer this question; however, it is beyond the scope of this study. The best strategy for manufactures and retailers may be to market sustainable packaging for each specific region of the U.S. since each state has different laws and opportunities to recycle plastic and Styrofoam products.

APPENDIX

APPENDIX A

Table 2.1 Definitions of the Variables and their Descriptive Statistics

Variables	Definition	Min (cent)	Max (cent)	Mean (cent)	Base Variables
Dependent variable					
Price per egg	A price per egg	0.06633	0.59667	0.23698	
Specialty Characteristics					
r, o, wm, owm, vd, and ne	DV* which is 1 for regular (*r*), organic (*o*), welfare-managed (*wm*), organic and welfare-managed (*owm*), vegetarian-fed (*vd*), and nutritionally-enhanced (*ne*) eggs, respectively and 0 otherwise	0	1	0.4198, 0.1481, 0.2305, 0.1111, 0.3868, and 0.2593	Regular (*r*)
Brands					
store, *regional*, and *national*	DV which is 1 for that type of brand, and 0 otherwise	0	1	0.4139, 0.2664, and 0.3197	Store brand (*store*)
Colors					
white, and *brown*	DV which is 1 for a white (brown) egg, and 0 for a brown (white) egg	0	1	0.4321, and 0.5679	White color (*white*)
Grades					
A, and *AA*	DV which is 1 for an egg is grade A (AA), and 0 if an egg is grade AA (A)	0	1	0.9508, and 0.0492	Grade A (*A*)
Types of Packaging					
foam, *plastic*, and *paper*	DV which is 1 for an egg package made from Styrofoam, plastic, and paper-pulp, respectively and 0 otherwise	0	1	0.2025, 0.4298, and 0.3678	Styrofoam (*foam*)

Table 2.1 (cont'd)

Variables	**Definition**	**Min (cent)**	**Max (cent)**	**Mean (cent)**	**Base Variables**
Size					
Medium, *large*, *extra large*, and *jumbo*	DV which is 1 for a medium, large, extra-large, and jumbo egg, respectively, and 0 otherwise	0	1	0.0459, 0.7156, 0.1651, and 0.0734	Medium size (*medium*)
Retailers					
Acme, *Giant, Pathmark, Safeway, Shopper, Shaws, Shoprite, Superfresh, Stop and Shop, Walmart, Wegmans, and Weis*	DV which is 1 for an egg sold by that retailers and 0 otherwise	0	1	0.0451, 0.0697, 0.1393, 0.1189, 0.0533, 0.0902, 0.0984, 0.0902, 0.0820, 0.0984, 0.0656, and 0.0492	Walmart (*walmart*)
Others					
Shell label	DV which is 1 for an egg with shell label, and 0 otherwise	0	1	0.1681	No shell label (*no shell label*)
Egg age	a number of days counted from when an egg is laid until it is bought at the store	1	41	14.02	
Unit size	a number of eggs per unit	6	60	12.45	

***Note:** DV represents a dummy variable.

Table 2.2 Results for Hedonic Prices of Egg Attributes

Attributes	**Coefficient (S.E.) Unit: Dollars**	
Dependent variable	*Price per egg*	
Specialty Characteristics		
o	0.165***	(-0.023)
wm	0.0357***	(-0.0122)
owm	-0.0881***	(-0.0267)
vd	-0.0065	(-0.0089)
ne	0.0230***	(-0.00877)
Brands		
regional	0.0395***	(-0.0125)
national	0.0533***	(-0.00939)
Colors		
brown	0.00186	(-0.00834)
Grades		
AA	0.0328**	(-0.0127)
Types of packaging		
plastic	0.0106	(-0.0114)
pulp	-0.00306	(-0.00936)
Sizes of eggs		
large	0.0456***	(-0.0119)
extra large	0.0575***	(-0.0119)
jumbo	0.0715***	(-0.0135)
Retailers		
Shaws	0.0601***	(-0.0116)
Stop and shop	0.0540***	(-0.0167)
Giant	0.0597***	(-0.0117)
Safeway	0.116***	(-0.0149)
Wegmans	0.00609	(-0.0145)
Weis	0.0393**	(-0.0189)
Shopper	-0.0125	(-0.0124)
Pathmark	0.0775***	(-0.0133)
Shoprite	0.0634***	(-0.0128)
Superfresh	0.0502***	(-0.013)
Acme	0.0645***	(-0.0146)
Others		
shell label	0.00425	(-0.0121)
egg age	0.000214	(-0.000371)
unit size	-0.00149**	(-0.000728)
Constant	0.0897***	(-0.0174)
Observations	207	
R-squared	0.812	

Note: * significant at 10%; ** significant at 5%; *** significant at 1%

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CHAPTER 3: FOOD MANUFACTURERS'

SUSTAINABLE PRODUCT LAUNCH STRATEGY: GAME THEORY APPROACH

3.1 Introduction

There are four key reasons why food manufacturers are interested in sustainable strategies, investing in sustainable practices, and/or launching a sustainable product in the market. First, launching sustainable products can be a public relations strategy of the firms to improve their brand image and exposure. There were 13,000 new sustainable food and beverages launched between 2005-10 (O'Donnell 2008). Consumers are more likely to realize which brands are green when brands are familiar and have good reputations in general, especially if brands have green marketing campaigns (O'Donnell 2008). The Accenture and United Nation Global Compact (Broder 2010) 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 also showed that CEOs realize that incorporating sustainability practices can be a source of cost efficiency and revenue growth even during an economic downturn (Broder 2010). Third, global retailers are using their market power to strongly encourage manufacturers to produce sustainable products. For example, Walmart, the world largest retailer, has more than 100,000 global suppliers and more than 8,000 stores, is in the process of creating a "Sustainability Index" (2014 completion date). It will measure the environmental performance of suppliers to inform its customers about a product's "life cycle". The intention is to improve efficiency by reducing costs and waste (Broder 2010). With Walmart's market power, its sustainability program is expected to influence not only other retailers but also manufactures in the near future. Lastly, consumers are demanding that manufacturers be more environmentally friendly (Oberholtzer, Greene, and Lopez 2006) and want to know where their food comes from and how it is produced. Eighty-four percent of U.S. consumers interviewed indicated that they sometimes or regularly purchase sustainable food and drink, especially those with local and recyclable packaging claims (O'Donnell 2008).

Although sustainability is at the forefront of most food manufacturer and retailing CEOs' minds, most food manufacturers are reluctant to implement sustainable practices, and develop and market new sustainable food products. In part, their reluctance appears to be driven by two primary issues: 1) a lack of technology to produce sustainable products or implement sustainable practices, and 2) a lack of a systematic decision model that includes extensive sustainable related variables, especially demand side variables.

This study constructs a model representing food manufacturers' decision making to launch a sustainable product. The model that will be developed in this paper is a culmination of product launch strategies, game theory, and the agribusiness literature. Several works study, both theoretically and empirically, the innovation strategies and launch strategies of firms in duopoly markets (Yoon and Lilien 1985; Acs and Audretsch 1987; Dockner and Jørgensen 1988; Debruyne et al. 2002; Bröring 2007). In particular, numerous industrial organization papers investigated new product launch strategies using a signaling game approach (Robertson, Eliashberg, and Rymon 1995), and reaction strategies approach (Debruyne et al. 2002). In the agribusiness field, several papers used game theory to construct agricultural product launch strategies (Russo, Cardillo, and Perito 2003; Hitsch 2006; Bröring 2007).

The model developed in this paper is later applied to the U.S. egg industry. There are four main reasons why the egg industry is a good industry to use as an example to understand manufacturers' decision making. First, eggs are an important commodity; i.e. it is globally one of the cheapest sources of protein (Zelman 2009), and has lots of vitamins and minerals (United States Department of Agriculture 2010b; Jegtvig 2013). Therefore, consumers frequently purchase eggs. Second, eggs are not a complicated food product, and consumers can easily understand the marketing message from manufacturers about sustainable attributes. Third, animal welfare and the new legislation concerning egg production has encouraged many egg manufacturers to begin marketing sustainable eggs (including free-range and cage-free eggs). Lastly, the cost and price premiums data for sustainable eggs as well as conventional eggs are easily accessible making simulation modeling feasible.

The egg industry in the U.S. is an important industry with a market size equal to $ 5.73 billion in 2010 (Patterson 2011). There are two main segments in the egg market, fresh eggs and egg substitutes. In 2010, fresh eggs had a market share equal to 93.5% or $ 5.36 billion (Patterson 2011); therefore, the study focuses only on the fresh egg market. Fresh egg categories include regular eggs and specialty eggs. Examples of specialty eggs are free-range/cage-free eggs, organic eggs, eggs fortified with Omega-3, low-cholesterol eggs, and vegetarian-fed eggs.

At this time, there is no legal definition for free-range or cage-free 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 the outside while cage-free eggs are laid by hens that live uncaged indoors, but do not necessarily have access to the outdoors. Consumers who have animal welfare concerns prefer and have a higher willingness to pay for a method of animal husbandry that allows hens to roam freely instead of being in cages[16] (Bennett 1998). Sustainable attributes can include recyclable packaging, free-range, and cage-free attributes. (Satimanon and Weatherspoon 2010) estimated values of sustainable egg attributes by using a hedonic price approach and found that the recyclable-claim attribute was insignificant. Therefore, in this study, sustainable eggs include only free-range and cage-free eggs.

The uniqueness of the approach used in this study lies in the ability to analyze the combination of four factors. First, this study captures the concern about the difference between consumers' maximum willingness to pay[17] for the sustainable and the conventional products that are the constant terms in the inverse demand functions. Second, the model captures the degrees of substitution between products, which include both the degree of substitution between different product types (conventional and sustainable products), and the degree of substitution between manufacturers' brands. Third, the study incorporates these dimensions within a food supply chain context, and simulations are generated using egg industry data. Lastly, the model can be extended to incorporate demand uncertainty in the sense that a firm does not know whether consumers are willing to pay a premium for a new sustainable food product.

[16] Hens are generally raised in a cage system. There are about **5%** of eggs in the U.S. (and 10% around the world) from non-cage housing systems (United Egg Producers 2011).
[17] In short, it will be called maximum willingness to pay instead of consumer's maximum willingness to pay from now on.

3.2 Objective

The objective of this study is to model the manufacturers' decision making process for launching a sustainable product to determine: 1) the conditions under which firms should launch the sustainable product; and 2) the conditions under which the leader firm's profit is higher than the follower firm's profit, that is, the conditions that encourage a firm to be a leader firm. Data from the egg industry will be used for simulations in order to parameterize and test the model and to better understand the sustainable egg market.

3.3 Methodology

Several methods are commonly used to determine under which conditions firms will market a new product and receive higher profits. These methods include empirical analysis, real options, and game theory when assessing product launch decision making. Several empirical studies analyzed factors and determinants that resulted in a successful launch of products. For examples, Benedetto (1999) used mail survey data to analyze factors that encourage the success of launching a product and suggested that the quality of marketing strategies are the most important factors. Henard and Szymanski (2001) employed a meta-analysis of the new product performance literature to find the drivers of new product success. They showed that product advantage, marketing potential, meeting customer needs, pre-development task proficiencies, and dedicated resources are important indicators for successful product launches. Debruyne et al. (2002) used a mail survey to study competitor's reactions to new launches. They found that competitors often react by changing prices; moreover, the characteristics of the new products determine patterns of competitive reactions. Narver, Slater, and MacLachlan (2004) used empirical data from a variety of businesses, and found that a proactive market orientation (the attempt to understand and to satisfy customers' latent needs) is important for a firm's new product success. These studies relied on quality firm level data that is not available for the egg industry; hence, these approaches were not used in this study.

Real options, which provides a mechanism in which the farmer's or firm's decision to adopt or launch a new product is determined solely based on the future stream of profits with respect to uncertainty. This approach is usually used at the product or industry level, given a level of uncertainty and fixed-investment costs. At the farm level, the adoption of new product studies focused on high fixed investment costs (Tzouramani and Mattas 2004; Tauer 2006; Stokes, Rajagopalan, and Stefanou 2008) and assumed continuous time and infinite period assumptions to project whether the farmers will adopt certain crops or not. The unit of analysis of those studies was at the farmer level; this paper's unit of analysis is at the manufacturer level. The different levels result in different assumptions for output prices; the farmer level having fixed prices because they are operating under perfect competition; and the manufacturer level which is assumed to be imperfect competition. Russo, Cardillo, and Perito (2003) combined real options and game theory to find product launch conditions in the Italian fruit-drink industry. They focused on uncertainty and the forms of innovation (monopoly of innovation, competitive innovation, and imitated innovation) and found that the option value of the research and development investment, the risk of failure, and competitors' strategies have significant impacts on product-innovation strategy. Real options studies mainly assume a level of uncertainty, which relates to high fixed costs and irreversible investment. However, in this study, egg manufacturers have low fixed costs and no irreversible investments. The manufacturers can use the same machine whether they want to produce a sustainable egg or conventional egg. Therefore, real options theory is not selected as a methodology to use in this study. In addition, real options theory also has a tractability issue as the model becomes more complex. The benefits of using game theory include: the price of the new and old product can be endogenously determined by the actions of the firms in the market; and the modeling in game theory is more tractable given the same level of complexity. Therefore, game theory is a more appropriate method of modeling this industry.

Most of the product launch literature using game theory focuses on high fixed investment cost industries such as Lint and Pennings (2001), Murto and Keppo (2002), and Lee and O'Connor (2003). Fulton and Giannakas (2004) used game theory to study genetically modified (GM) technology adoption to produce and market GM food products. They found that the launch conditions depend on the preferences of consumers and producers, and life science companies' objectives. That study used a two-stage sequential game that did not model the stage after the adoption when other producers can also adopt and market GM products. That is, they did not consider a follower firm's decision making to adopt the new technology and launch the GM product to the market. Fulton and Giannakas' model informs the development of the model in this paper which considers under which condition a follower firm should launch a sustainable product.

The past studies that employed game theory did not focus on the change in profits when competitors decide to supply the same type of product later. The model has to have a different structure to allow homogenous preferences of consumers; variability in willingness to pay; and allow consumers to consume both types of goods simultaneously. In addition, the model needs to allow for stages when a follower firm also decides to launch a sustainable product as mentioned before.

The model must allow for two players[18], a leader and a follower, in a regional market and focus on the importance of a relative maximum willingness to pay for a sustainable product, a relative marginal cost of a sustainable product, and a degree of substitution between two brands and two types of products. Lastly, the model should be designed for simulation use.

3.4 Model

In this analysis, there are two firms, each firm produces only one type of product, either a conventional product or a sustainable product in each stage for simplicity. There are four stages in the analysis as shown in Figure 3.1. Stage 1 is a status quo stage in which both leader (firm i) and follower (firm j) produce a conventional product (c). Both firms set price as a strategy simultaneously for their branded conventional product (Bertrand game). This stage will continue as a repeated game until the leader decides to launch a sustainable product. Stage 2 happens when the leader firm has the know-how to produce a sustainable product (s) and decides to launch it to make a higher profit. In this stage, both firms use price as the choice variable and set their prices simultaneously (Bertrand game). This stage is repeated until the follower also decides to launch a sustainable product. When this occurs, stage 3 is entered and both leader and follower firms produce sustainable branded products. The leader sets the price first and the follower sets the price of its product later (Stackelberg price leader game) since the leader first produced the sustainable product in stage 2. This stage occurs once and the market moves to stage 4, which is similar to stage 1, except both firms are producing sustainable products. This series of stages are intended to represent the innovation cycle of a new product launch. Stage 2 to

[18] Even though there are two firms in this model, we can apply the model in a general case when there is a leader and many followers.

stage 4 may not exist in reality. They exist only when the leader and/or follower's launch conditions are satisfied.

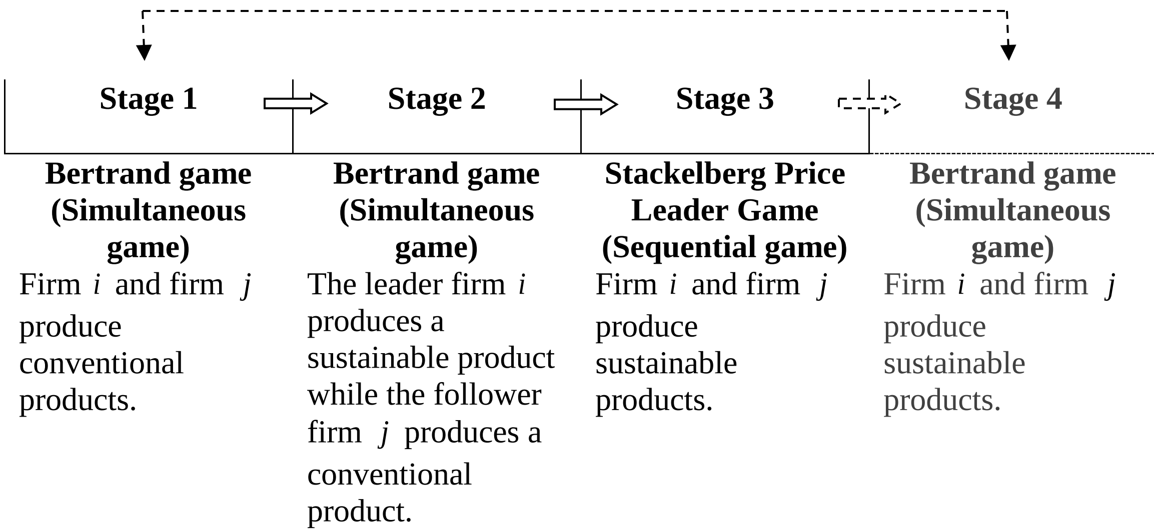

Figure 3.1 Stages and types of food product innovation games.

This study is based on a simple model for two vertically differentiated products[19] (Dixit 1979; Singh and Vives 1984; Shy 1995) because branded products are similar but they are not homogeneous. The structure of inverse demand functions for the vertically differentiated products of firm i in stage 1 is represented by equation (3.1) where $p_{c,i}$ is the price of the conventional product of firm i; a_c represents the maximum willingness to pay for a conventional product, which has a value greater than zero; and $q_{c,i}$ is the quantity demand for the conventional product of firm i.

$$p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j} \tag{3.1}$$

[19] Vertically differentiated products are defined as products that are different in quality.

The negative sign of $q_{c,i}$ shows an inverse relationship between price and quantity[20] (law of demand). Also in equation (3.1), $q_{c,j}$ is the quantity of the conventional product of firm j. The negative sign of $q_{c,j}$ shows a negative relationship between price and quantity of the substitute good. The coefficient γ_1 is the degree of substitution between the conventional products of firm i and firm j in stage 1, and has a value between zero and one (Singh and Vives 1984; Poddar and Saha 2010). If γ_1 is equal to zero, firm i is a monopoly, that is, the quantity of the "substitute" good 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 of the degree of substitution or the products are more similar.

The inverse demand functions for each stage are as follows:

Stage 1: Bertrand Game

$$p_{c,j} = a_c - q_{c,j} - \gamma_1 q_{c,i}. \qquad (3.2)$$

Stage 2: Bertrand Game

$$p_{s,i} = a_s - q_{s,i} - \gamma_2^s q_{c,j}, \text{ and} \qquad (3.3)$$

$$p_{c,j} = a_c - q_{c,j} - \gamma_2^c q_{s,i}. \qquad (3.4)$$

Stage 3: Stackelberg Price Leader Game

$$p_{s,i} = a_s - q_{s,i} - \gamma_3 q_{s,j}, \text{ and} \qquad (3.5)$$

$$p_{s,j} = a_s - q_{s,j} - \gamma_3 q_{s,i}. \qquad (3.6)$$

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[20] The coefficient of $q_{c,i}$ is normalized to one for simplicity.

The structure of the inverse demand functions of firm i and j in every stage is similar except the degree of substitution in stage 2 is asymmetrical because the types of products of firm i and j are different. The inverse demand functions in stages 1 and 3 are similar[21]. In both stages, firms produce the same type of products; thus the constant terms in equations (3.1) and (3.2), a_c, are the same; as well as, the constant terms in equations (3.5) and (3.6), a_s, are the same. Moreover, the degrees of substitution in stages 1 and 3 are symmetric. In stage 2, the constant term in the inverse demand functions for firm i and j and the degrees of substitution in equations (3.3) and (3.4) are different since they produce two different types of branded products.

The model assumes that $0 < \gamma_2^s \le \gamma_2^c \le \gamma_3 \le \gamma_1 < 1$. γ is always greater than zero because the 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 stage 1, represents the brand difference of firm i and j. γ_2^s and γ_2^c are the degrees of substitution in stage 2 from the inverse demand functions for the sustainable product and the conventional product respectively while technically representing the brand and product differences inherent in stage 2. We assume here that γ_2^s and γ_2^c represent only the product differences because the brand differences have a small effect relative to product differences, and we would like to keep the model as simple as possible. Given this, γ_2^c is greater than γ_2^s because a consumer that prefers a sustainable product has a lower degree of substitution for a

[21] The inverse demand functions in stage 4 are similar to equations (3.1) and (3.2) except all subscript c's are replaced with s's.

conventional product while a consumer who prefers 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 is likely to have more difficulty switching to the discounted conventional eggs. However, if free-range eggs are on sale and have a price close to conventional eggs, a consumer who normally purchases conventional eggs is likely to switch to the discounted free-range eggs relatively easily. γ_3 is the degree of substitution in stage 3 representing the brand difference and the brand loyalty for the 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 sustainable product first supports the leader's goodwill and reputation).

The model also assumes 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 consumers on average have a greater willingness to pay for a sustainable product than a conventional one. In this model, the marginal cost of production of the sustainable product (c_S) is greater than the marginal cost of the conventional product[22] (c_C). We assume that the marginal cost is less than the maximum willingness to pay, i.e., $a_C > c_{C,i}$, $a_C > c_{C,j}$, $a_S > c_{S,i}$, and $a_S > c_{S,j}$. The industry literature shows that the production cost of a sustainable egg is higher than the cost of producing a conventional egg by 20 – 66% ("Impacts of Banning Cage Egg Production in the United States A Report Prepared for United Egg Producers" 2009). The

[22] Sustainable practices such as using wind energy and/or solar energy to substitute gas energy can reduce production cost of firms; however, launching sustainable products to capture higher price premium usually creates an additional cost. For example, Sumner et al. (2008) showed that pullets, feed, housing, and labor costs of non-cage system are higher than those costs of cage system.

derivation for the equilibrium profits in stage 1($\pi_{c,i}{}^{1}*$ and $\pi_{c,j}{}^{1}*$), stage 2 ($\pi_{s,i}{}^{2}*$ and $\pi_{c,j}{}^{2}*$), and stage 3 ($\pi_{s,i}{}^{3}*$ and $\pi_{s,j}{}^{3}*$) can be found in appendix B. Appendix C presents the expansion of the model to include uncertainty on the maximum willingness to pay for a sustainable product. That is, manufacturers expect that the maximum willingness to pay for a sustainable product is equal to a_S with a probability θ, and a_C with a probability 1- θ. Moreover, the proof of all propositions and standard findings are shown in appendix D.

3.5 Egg Industry Simulations

There are many studies about the retail price premium of sustainable eggs. It ranges from 47.72% to 105.15% over conventional eggs as shown in Table 3.1.

Table 3.1 The price premium of free-range/cage-free eggs and the source of information.

Source	Price premium of a free-range or cage-free egg (%)
Satimanon and Weatherspoon, 2010	47.72
Chang, Lusk and Norwood , 2010	57.00
Mintel, 2008	60.00
United Egg Producer, --- (based on the USDA weekly retail shell egg)	105.15

"Impacts of Banning Cage Egg Production in the United States A Report Prepared for United Egg Producers" (2009) collected data about the additional cost for sustainable egg production at the farm level from several sources. The additional cost or the marginal cost of the sustainable egg ranged from 20% to 66% higher than the marginal cost of the conventional egg production. In addition, Sumner et al. (2008) showed that the difference of production costs between conventional cage production systems ($ 0.75 per dozen) and non-cage production system

($ 1.05 per dozen) were equal to about 41%. However, there is no data for egg production costs at the manufacturer level. Therefore, we assume that all of the costs at the manufacturer level for the sustainable and the conventional eggs are the same except the cost for the raw material (eggs from farmers). Moreover, $ 0.75 is the cost for the conventional egg (c_C) or it is assumed that the egg price sold by farmers is the same as the farmers' cost. This is for simplicity since there is no interest in estimating the farmers' margin in this study. The average price for a dozen of grade A large eggs in 2010 (United States Department of Labor 2011) was $1.66 and was used in the simulations.

The parameters from the egg industry are used for illustrative purposes to create simulations and graphs for each proposition/standard finding. Moreover, parameters from the egg industry and the solution from the profit equations in appendix B are used to simulate and explain the launching of free-range or cage-free eggs. Mathematica is employed for the simulations and checking of all propositions and standard findings. All of the simulations in each proposition show the relationship between the differences in profits and parameters. There are two scenarios for the simulations; the best case and worst case scenarios. In the best case scenario, we use the highest price premium value (105.15%) and the lowest additional marginal cost (20%) for the sustainable egg manufacturer while in the worst case scenario, we use the lowest price premium value (47.72%) and the highest additional marginal cost (66%).

To comply with the variables in the model for the best (worst) case scenario[23], $\frac{c_{s,i}}{c_{c,j}}$ in stage 2 is equal to 1.2 (1.66), and the proportion of prices in stage 2 $\left(\frac{p_{s,i}^{2*}}{p_{c,j}^{2*}}\right)$ is equal to 2.05 (1.48). The steps and the example of simulation are shown in appendix E.

3.6 Results

The results are divided into two parts to fulfill two objectives: 1) conditions under which firms launch a sustainable product, and 2) conditions that encourage a firm to be a leader. The conditions are found under some restrictions; therefore, comparative statics is used to explain the situation where the restrictions do not hold. Exploration of the conditions under which firms decide to launch a sustainable product is conducted; then, consideration for the conditions that encourage a firm to be a leader. The egg industry simulations are presented in each proposition as well as the standard findings in order to help the reader understand the intuition of the results and the egg industry modeling.

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[23] When $c_{c,j}$ equals 1, $c_{s,i}$ (which is 20% higher than $c_{c,j}$ in the best case scenario) equals 1 + 0.2 = 1.2. Thus, $\frac{c_{s,i}}{c_{c,j}} = \frac{1.2}{1}$ = 1.2. Similarly, when $p_{c,j}^{2*}$ equals 1, $p_{s,i}^{2*}$ (which has a price premium equal to 105.15% in the best case scenario) equals 1 + 1.05. Therefore, $\frac{p_{s,i}^{2*}}{p_{c,j}^{2*}}$ equals $\frac{1+1.05}{1}$ = 2.05.

3.6.1 Conditions under which firms launch a sustainable product

Backward induction allows us to determine under which conditions the manufacturers launch a sustainable product. The leader firm i considers the reaction of firm j before deciding to launch a sustainable product. That is, the leader's decision-making depends on whether the follower will decide to launch a sustainable product later or not. From figure 3.2, the decision of the leader to launch a sustainable product (move to stage 2) does not depend on only the comparison of the leader's profits in stages 1 and 2 ($\pi_{c,i}^{1}*$ and $\pi_{s,i}^{2}*$), but also on the comparison of the leader's profits in stages 1 and 3 ($\pi_{c,i}^{1}*$ and $\pi_{s,i}^{3}*$).

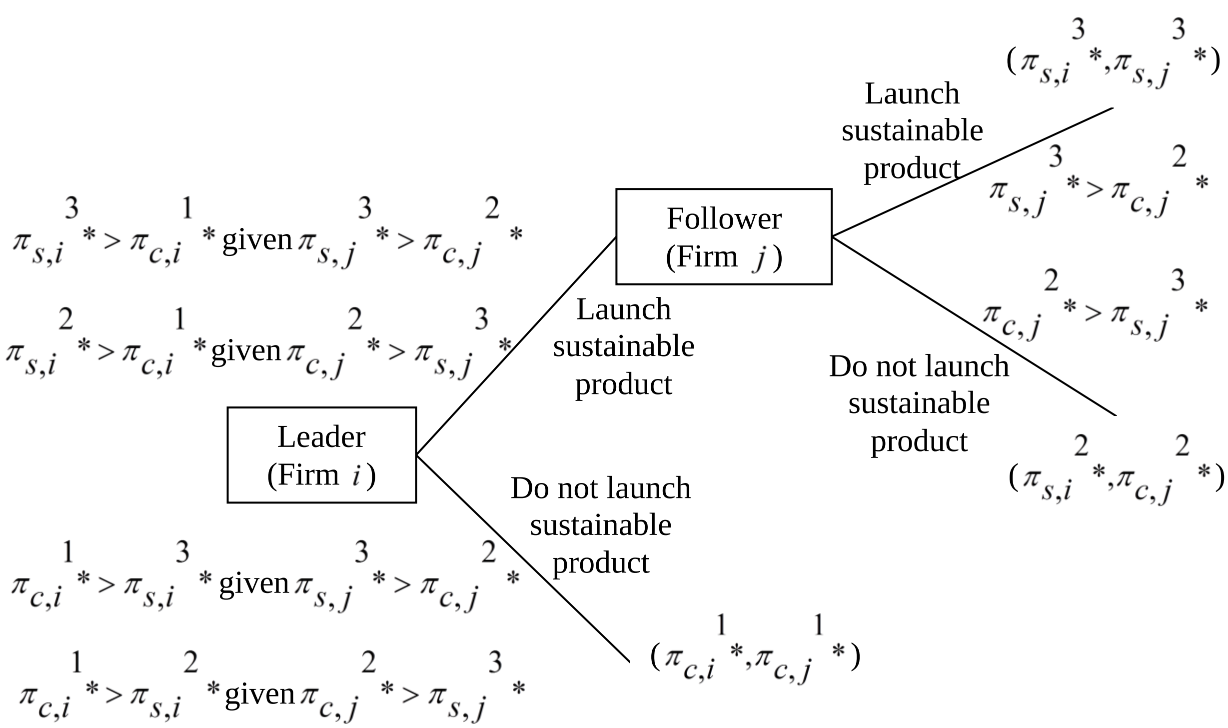

Figure 3.2 Backward induction decision tree for manufacturer's decision to launch a sustainable product.

From figure 3.2, there are three possible outcomes. The first one is that the follower decides to launch a sustainable product if $\pi_{s,j}^{3}* > \pi_{c,j}^{2}*$, and the leader also decides to launch a sustainable product if $\pi_{s,i}^{3}* > \pi_{c,i}^{1}*$. Payoffs in this case are profits in stage 3. The second outcome is if the follower does not decide to launch a sustainable product ($\pi_{c,j}^{2}* > \pi_{s,j}^{3}*$), and the leader decides to launch a sustainable product if $\pi_{s,i}^{2}* > \pi_{c,i}^{1}*$. Payoffs in this case are profits in stage 2. The last outcome is where no firm decides to launch a sustainable product. That is, the leader does not decide to launch a sustainable product (either $\pi_{c,i}^{1}* > \pi_{s,i}^{3}*$ or $\pi_{c,i}^{1}* > \pi_{s,i}^{2}*$). In this case, payoffs are equal to profits in stage 1. Next, according to backward induction we will consider the follower's decision making and then move to the leader's decision making about launching a sustainable product.

3.6.1.1 Follower's decision making for launching a sustainable product

Consider the *follower* firm's decision making by comparing the profits when launching a sustainable product ($\pi_{s,j}^{3}*$) and when still producing a conventional product ($\pi_{c,j}^{2}*$). The follower will decide to launch a sustainable product when there are higher profits from launching a sustainable product ($\pi_{s,j}^{3}* > \pi_{c,j}^{2}*$).

Given that the leader has already launched a sustainable product, the follower has to decide whether it is more profitable to produce a "me too" product or not. This leads to the first proposition (the derivations can be found in appendix D).

Proposition 1: When $\gamma_2^c = \gamma_2^s = \gamma_3$, $c_{s,i} = c_{s,j}$, and $\frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}$, the follower will decide to launch a sustainable product and move to stage 3 if:

a. $0 < \gamma_2^s \leq 0.75$, or

b. $0.75 < \gamma_2^s < 1$ and $1 < \frac{c_{s,j}}{c_{c,j}} < \frac{(\left(\gamma_2^s\right)^2 - 2)^2}{0.25[(\gamma_2^s - 2)((\gamma_2^s + 3)(\gamma_2^s - 4)\gamma_2^s - 8)\gamma_2^s - 16]}$.

Explanation: Given the restrictions that the: 1) degrees of substitution in stages 2 and 3 are the same ($\gamma_2^c = \gamma_2^s = \gamma_3$); 2) costs of both firms to produce sustainable products are the same ($c_{s,i} = c_{s,j}$); and 3) relative cost of a sustainable over conventional product[24] is equal to its relative maximum willingness to pay $\left(\frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}\right)$, then the follower decides to launch a sustainable product. The intuition for proposition 1a is that the follower considers the consumers' perception as a *key factor* for its sustainable product launch decision. That is, when consumers realize that conventional and sustainable products are different ($0 < \gamma_2^s \leq 0.75$), and have a willingness to pay more for the sustainable product; a sustainable product market will mature

[24] From now on, we will call the term $\frac{c_{s,j}}{c_{c,j}}$ as a relative cost of a sustainable product and $\frac{a_s}{a_c}$ as a relative maximum willingness to pay for a sustainable product.

enough such that the follower launches a sustainable product to take market share from the leader. The *second factor* the follower considers is the relative cost of a sustainable product $\left(\frac{c_{S,j}}{c_{C,j}}\right)$. Proposition 1b shows that even if consumers do not realize the difference between two types of products ($0.75 < \gamma_2^S < 1$), the follower still decides to launch a sustainable product if the marginal costs of the sustainable and conventional products are close enough, or when a relative cost of a sustainable product is low enough

$$\left(1 < \frac{c_{S,j}}{c_{C,j}} < \frac{(\left(\gamma_2^S\right)^2 - 2)^2}{0.25[(\gamma_2^S - 2)((\gamma_2^S + 3)(\gamma_2^S - 4)\gamma_2^S - 8)\gamma_2^S - 16]}\right).$$

Figure 3.3 presents simulation results for profit comparisons between stages 2 and 3 for the follower firm assuming[25] a_S = 5, and varying the degrees of substitution ($\gamma_2^C = \gamma_2^S = \gamma_3$) for three levels of relative costs of a sustainable product $\left(\frac{c_{S,j}}{c_{C,j}}\right)$. The relative cost levels were 1.2 (the best case scenario), and 1.66 (the worst case scenario). Figure 3.3 shows that over these ranges, the follower firm will launch a sustainable product at all levels of relative costs as long as the degree of substitution is not too high (below 0.97 for $\frac{c_{S,j}}{c_{C,j}}$ = 1.2 (the best case scenario), and

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[25] a_S = 5 approximately corresponds with the demand for eggs/person/10 weeks. That is, when a_S = 5, the minimum value of a total quantity in stage 2 is equal to 2.68 dozen eggs. According to "Per Capita Consumption of Eggs (shell) in the U.S. 2009 | Statistic" (2011), egg consumption per capita per year was 172.9 eggs. Therefore, on average a person consumes at least 2.68 eggs per 68 days or about 10 weeks. a_S is stable across a wide range of values in terms of the shapes of the curves but the scale changes in magnitude.

below 0.93 for $\frac{c_{S,j}}{c_{C,j}}$ = 1.66 (the worst case scenario). This also shows that as the new technology cost decreases ($\frac{c_{S,j}}{c_{C,j}}$ also decreases), the higher range of γ_2^S allows the follower to get higher profits when launching a sustainable product. To correspond with proposition 1, figure 3.3 shows that for all values of $\frac{c_{S,j}}{c_{C,j}}$, the follower receives higher profit when launching a sustainable product if γ_2^S is lower than 0.75 or consumers realize that the two types of products are different (proposition 1a). Moreover, the lower relative cost of a sustainable product $\left(\frac{c_{S,j}}{c_{C,j}}\right)$, the higher the chance that the follower will decide to launch a sustainable product in order to earn higher profits (proposition 1b).

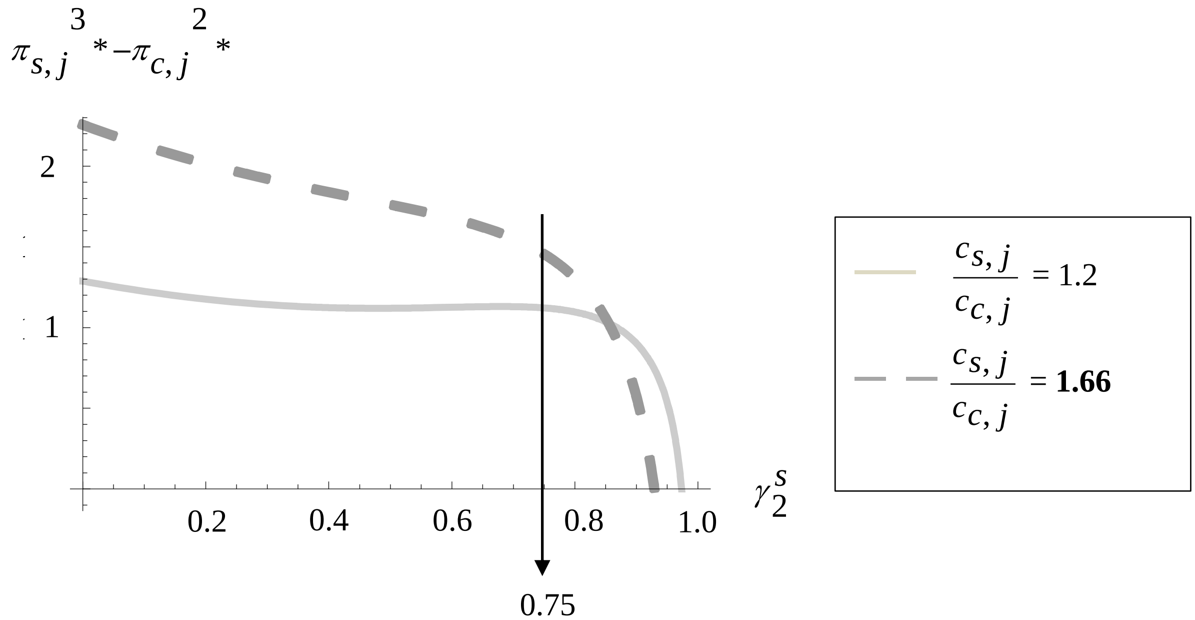

Figure 3.3 Profit simulation between stages 2 and 3 for the follower firm varying the degrees of substitution ($\gamma_2^c = \gamma_2^s = \gamma_3$) for three levels of relative costs of a sustainable product.

Next, we relax the first assumption such that $\gamma_2^c = \gamma_2^s \neq \gamma_3$ which is more realistic meaning; consumers realize the difference in product types is more than the difference in brands. For example, consumers feel that a cage-free egg and a conventional egg are more different than a brand A egg and a brand B egg. Figure 3.4 shows graphs of the difference in follower's profits in stages 2 and 3 ($\pi_{s,j}^{3} * - \pi_{c,j}^{2} *$) when γ_3 is varied by setting $\frac{c_{s,j}}{c_{c,j}} = 1.66$, and $a_s = 5$.

Figure 3.4 shows that given $\gamma_2^c = \gamma_2^s \neq \gamma_3$, the shapes of the graphs of the difference in profits ($\pi_{s,j}^{3} * - \pi_{c,j}^{2} *$) are the same when we vary γ_3. Therefore, the intuition of proposition 1 is valid even when we relax the assumption $\gamma_2^c = \gamma_2^s = \gamma_3$ to be $\gamma_2^c = \gamma_2^s \neq \gamma_3$.

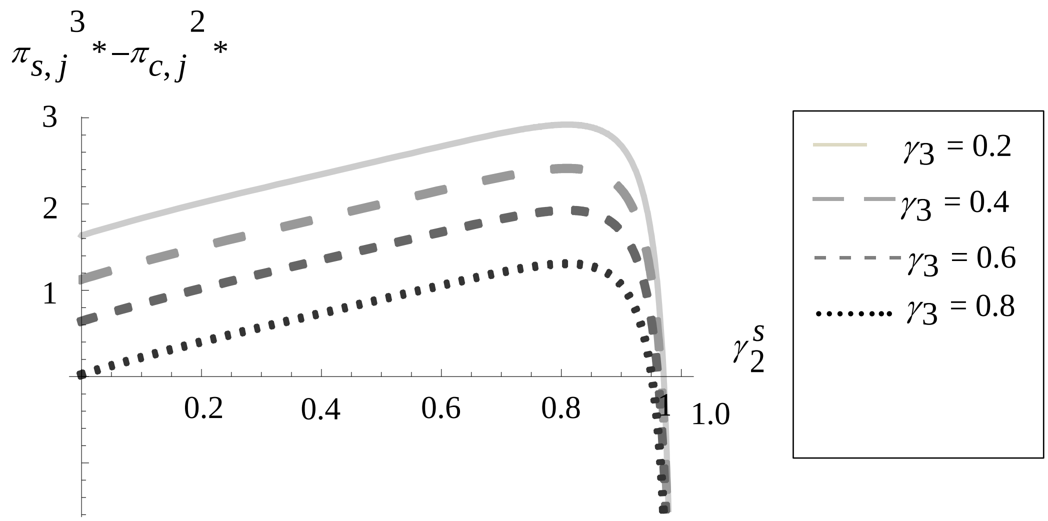

Figure 3.4 Profit simulation[26] between stages 2 and 3 for the follower firm varying the degrees of substitution in stage 2 ($\gamma^c_2 = \gamma^s_2$) for four levels of degree of substitution (0.2, 0.4, 0.6, and 0.8) in stage 3.

Without any restrictions, comparative statics shows the difference in profits will increase if the cost to produce a sustainable product declines $\left(\frac{\partial(\pi^3_{s,j}* - \pi^2_{c,j}*)}{\partial c_{s,j}} < 0\right)$. That complies with proposition 1b. When the follower has a technology to reduce the cost of a sustainable product, the follower decides to launch a sustainable product to get a higher profit ($\pi^3_{s,j}* - \pi^2_{c,j}* > 0$).

Next, profitability when there are sustainable eggs in the market already is explored. The values, which are used in the simulation in the best (worst) case are: 1) $\frac{c_{s,i}}{c_{c,j}}$ = 1.20 (1.66), 2)

[26] Note, γ_3 is greater than γ^s_2; therefore consider only the part where γ_3 is higher than γ^s_2.

$\frac{p_{s,i}^{2*}}{p_{c,j}^{2*}}$ = 2.05 (1.48), 3) $c_{c,j}$ = 0.75 per dozen, 4) $\gamma_2^c = \gamma_2^s = \gamma_3$, and 5) $p_{c,j}^{2*}$ = 1.21 per dozen[27]. The variables in the model that cannot be observed are the levels of maximum willingness to pay (a_c and a_s) and the degree of substitution (γ). However, simulation can be used to understand the unobserved variables. Figure 3.5 shows the relationship between $\frac{a_s}{a_c}$ and γ. That is, when consumers understand that two types of eggs are different (γ approaches zero), consumers would like to pay more for a sustainable product or they have a higher relative maximum willingness to pay for a sustainable egg.

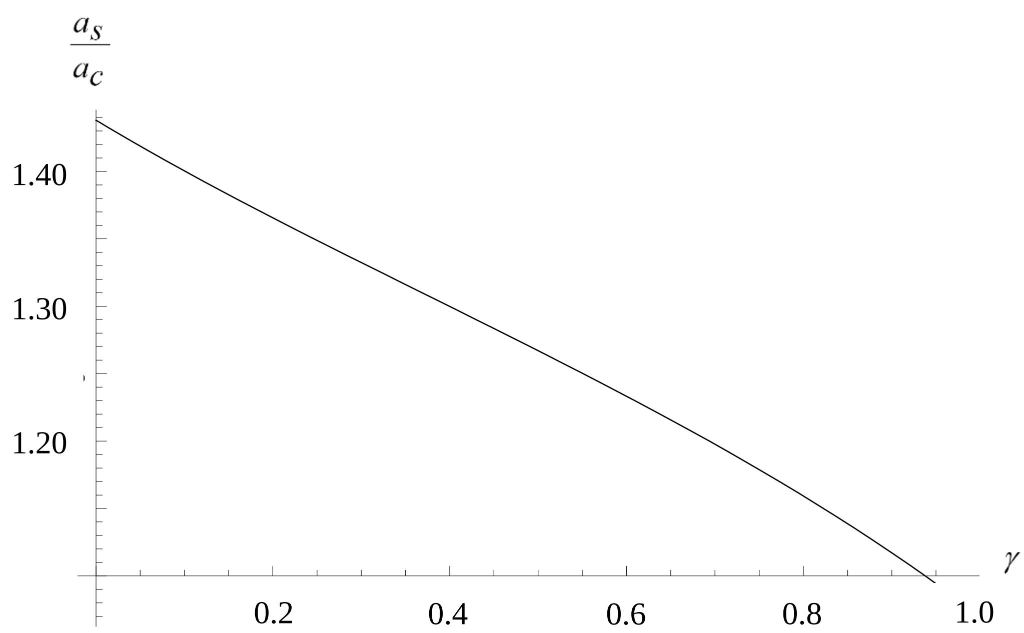

Figure 3.5 Simulation of the relative maximum willingness to pay for a sustainable product $\left(\frac{a_s}{a_c}\right)$ varying degrees of substitution ($\gamma = \gamma_2^c = \gamma_2^s = \gamma_3$).

[27] This is the wholesale price per dozen of conventional eggs in 2008 (United States Department of Agriculture 2010a).

From the simulation of both the best and worst cases, the follower's equilibrium price of a sustainable egg in stage 3 is higher than the follower's equilibrium price of a conventional egg in stage 2 ($p_{s,j}^{3}* > p_{c,j}^{2}*$), and so is the follower's equilibrium quantity ($q_{s,j}^{3}* > q_{c,j}^{2}*$). Note, even in the worst case, the follower's profit when launching the sustainable eggs is higher than the follower's profit when producing the conventional eggs ($\pi_{s,j}^{3}* > \pi_{c,j}^{2}*$); therefore, **the follower decides to launch the sustainable egg product.**

3.6.1.2 Leader's decision making for launching a sustainable product

The leader's decision making to launch a sustainable product is conditional on the follower's decision making. That is, if the follower decides to launch a sustainable product, the leader will compare its profits in stages 1 and 3 and decide to launch a sustainable product when getting a higher profit ($\pi_{s,i}^{3}* > \pi_{c,i}^{1}*$). However, given that the follower does not decide to launch a sustainable product, the leader has to compare its profits in stages 1 and 2 instead, and decide to launch a sustainable product when in stage 2 profits are higher than in stage 1 ($\pi_{s,i}^{2}* > \pi_{c,i}^{1}*$).

When the leader assumes that *the follower will launch* a sustainable product after the leader launches is modeled in the next two propositions.

Proposition 2: When either (a) $\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}$, and $\gamma_1 = \gamma_3$ or (b) $\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}$, $c_{c,i} = c_{c,j}$, and $c_{s,i} = c_{s,j}$, the leader will decide to launch a sustainable product and move to stage 2 in order to get a higher profit ($\pi_{s,i}{}^{3*} > \pi_{c,i}{}^{1*}$).

Explanation: Assuming that the follower will launch a sustainable product later, proposition 2 expresses the conditions under which the leader launches a sustainable product by comparing the leader's profits in stages 1 and 3. There are two sets of conditions under which the leader will decide to launch a sustainable product to get a higher profit ($\pi_{s,i}{}^{3*} > \pi_{c,i}{}^{1*}$). Those are, (a) relative costs of a sustainable product of both firms are the same and equal to the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}\right)$ and the degree of substitution in stages 1 and 3 are the same ($\gamma_1 = \gamma_3$), and (b) $\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}$ and firms have the same costs to produce the same types of products ($c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$).

The main idea of this proposition is that the leader firm decides to launch a sustainable product when ***its cost in relative terms equals the consumer's relative maximum willingness to pay***. Decomposing the cost of a sustainable product ($c_{s,i}$) and the consumer's maximum willingness to pay for a sustainable product shows $c_{s,i} = c_{c,i} + \Delta c$, and $a_s = a_c + \Delta a$ where Δc is an additional cost to produce a sustainable product and Δa is the additional maximum willingness to pay for a sustainable product. $\frac{c_{s,i}}{c_{c,i}} = \frac{a_s}{a_c}$ can be rearranged as $\frac{c_{s,i}}{a_s} = \frac{c_{c,i}}{a_c}$ or

$\frac{c_{c,i} + \Delta c}{a_c + \Delta a} = \frac{c_{s,i}}{a_s} = \frac{c_{c,i}}{a_c}$. Intuitively, the leader decides to launch a sustainable product when the additional cost to produce a sustainable product can be covered by the additional maximum willingness to pay for a sustainable product. That is, Δc has to be equal to $\frac{c_{c,i} * \Delta a}{a_c}$, or $\frac{\Delta c}{\Delta a} = \frac{c_{c,i}}{a_c} < 1$. Therefore, an egg manufacturer will be profitable when producing a sustainable egg if the additional part costs less than an additional maximum willingness to pay such that $\frac{\Delta c}{\Delta a} = \frac{c_{c,i}}{a_c}$, holds.

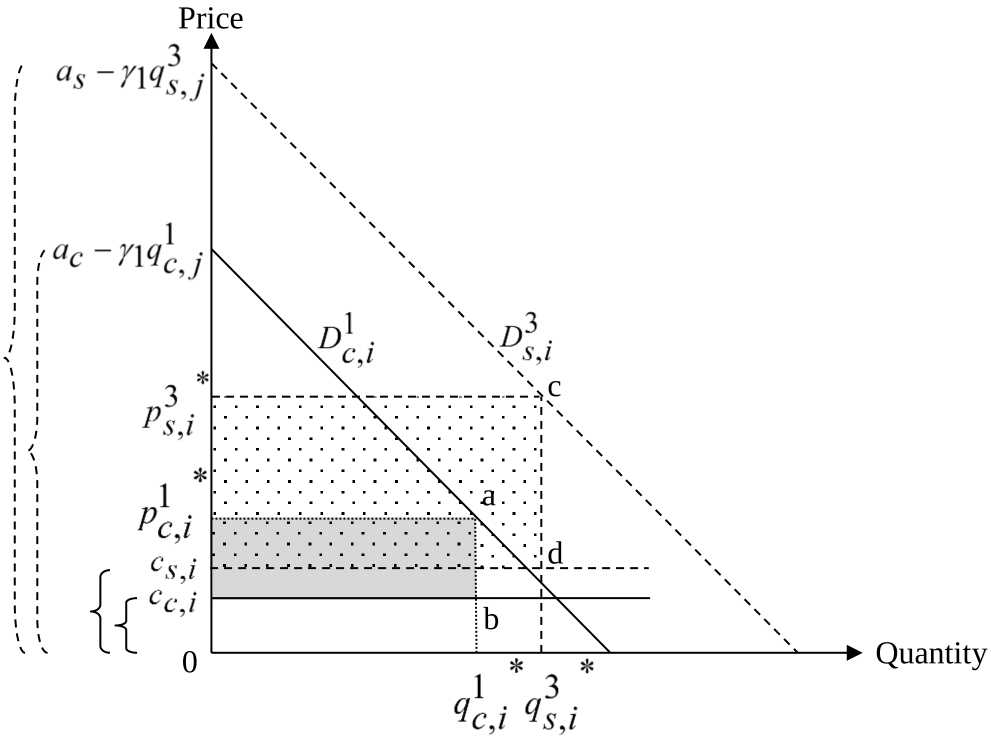

Figure 3.6 Leader's profits in stages 1 and 3
when the relative cost of a sustainable product of both firms are the same and equal to the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}\right)$ and degrees of substitution in stages 1 and 3 are the same ($\gamma_1 = \gamma_3$). (Condition set (a) holds.)

Figure 3.6 illustrates proposition 2 with condition set (a) where $D_{c,i}^1$ and $D_{s,i}^3$ are demands for a conventional product from firm i in stage 1 and a sustainable product from firm i in stage 3, respectively. $D_{c,i}^1$ has the same slope as $D_{s,i}^3$, which is equal to -1, but the y-intercept will be lower because the maximum willingness to pay for a sustainable product is higher than the one paid for a conventional product ($a_s > a_c$). The equilibrium prices and quantities ($p_{c,i}^{1\,*}$, $q_{c,i}^{1\,*}$, $p_{s,i}^{3\,*}$, and $q_{s,i}^{3\,*}$) are arbitrarily determined in figure 3.6 since they are predetermined by solving the equilibrium in the oligopoly market (appendix B). Firm i 's profits in stages 1 and 3 are $c_{c,i}$ ba $p_{c,i}^{1}{}^{*}$, and $c_{s,i}$ dc $p_{s,i}^{3}{}^{*}$, respectively. Graphically, $\frac{c_{s,i}}{c_{c,i}} = \frac{a_s}{a_c}$ shows that the leader's profit when launching a sustainable product is higher ($c_{c,i}$ ba $p_{c,i}^{1}{}^{*}$ < $c_{s,i}$ dc $p_{s,i}^{3}{}^{*}$). The graph and explanation of proposition 2 with condition set (b) is similar to figure 3.6. The difference is that the costs for both firms are the same for conventional and sustainable products ($c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$) in this case, but the degrees of substitution in stages 1 and 3 are not necessarily the same ($\gamma_1 \neq \gamma_3$). Hence, the y-intercepts of the demands in stage 3 are different, which results in differences in the equilibrium price and quantity.

The egg industry simulation results when comparing the leader's profits in stages 1 and 3, and assuming the additional cost of a sustainable product equals 66% (the worst cost case) are shown in figures 3.7.1 and 3.7.2. Figure 3.7.1 shows the simulation results when $\gamma_1 = \gamma_3$, but neither $c_{c,i} = c_{c,j}$ nor $c_{s,i} = c_{s,j}$ (condition set (a)) while figure 3.7.2 shows the simulation results when $c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$, but $\gamma_1 \neq \gamma_3$ (condition set (b)). Figures 3.7.1, and 3.7.2 show when consumers realize products from the two brands are more different, hence it is more profitable for the leader to launch a sustainable product (lower value of γ , higher value of $\pi_{s,i}^{3}{}^{*} - \pi_{c,i}^{1}{}^{*}$). For each value of γ , figure 3.7.1 shows that the levels of the leader's difference in profits in stages 3 and 1 ($\pi_{s,i}^{3}{}^{*} - \pi_{c,i}^{1}{}^{*}$) are higher when the leader has a cost advantage in the production of a sustainable product[28] ($c_{s,i} < c_{s,j}$) than when it does not. Moreover, without any restrictions, the comparative static results also show that the leader will get a higher profit from launching a sustainable product when the leader has a lower cost of a sustainable product. Lastly, both figures 3.7.1 and 3.7.2 also show that $\pi_{s,i}^{3}*$ is always greater than $\pi_{c,i}^{1}*$ ($\pi_{s,i}^{3}* - \pi_{c,i}^{1}* > 0$), and the larger value of the maximum willingness to pay for a sustainable product (a_s) results in a larger value of profit difference ($\pi_{s,i}^{3}* - \pi_{c,i}^{1}*$). That is, when consumers are willing to pay more for a sustainable product, the leader will get a higher profit when launching a sustainable product.

[28] From figure 3.7.1, the dashed lines illustrate the differences in profits of firm i in stages 1 and 3 ($\pi_{s,i}^{3}* - \pi_{c,i}^{1}*$) when firm i has a cost *disadvantage* in producing a sustainable product ($c_{s,i} > c_{s,j}$) while the solid lines illustrate $\pi_{s,i}^{3}* - \pi_{c,i}^{1}*$ when firm i has a cost *advantage* in producing a sustainable product ($c_{s,i} < c_{s,j}$). Hence, the solid lines are above the dashed lines for the same γ_3.

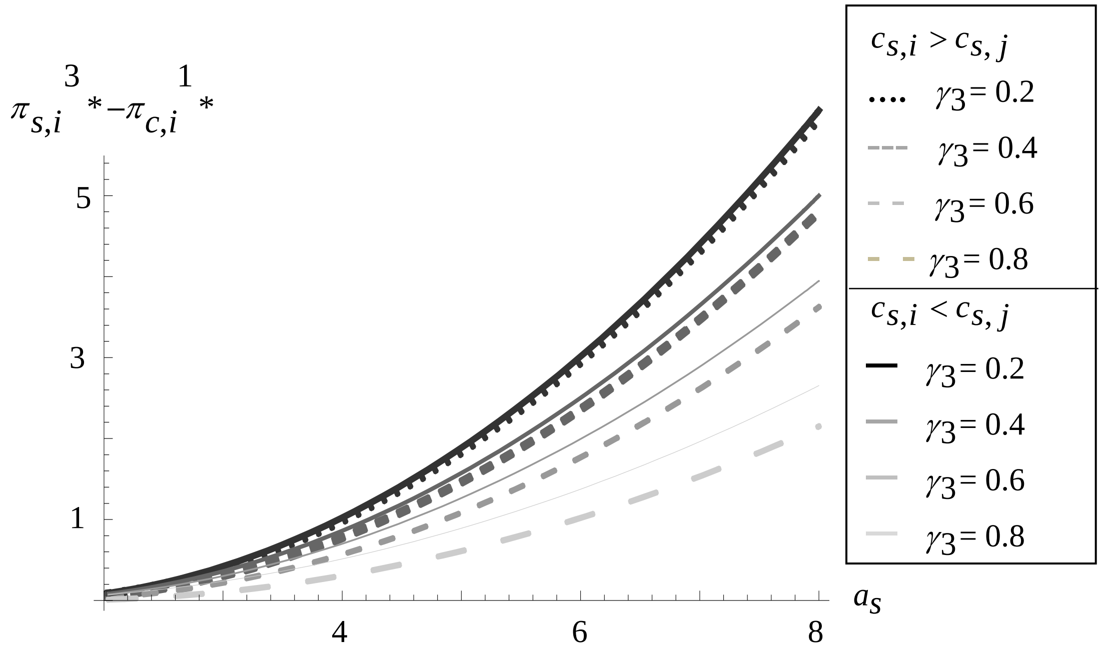

Figure 3.7.1 Profit simulation between stages 1 and 3 for the leader ($\pi_{s,i}^{3*}-\pi_{c,i}^{1*}$) when condition set (a) holds and varying the maximum willingness to pay for a sustainable product (a_s) for four levels of degrees of substitution (0.2, 0.4, 0.6, and 0.8) in stage 3 (γ_3).

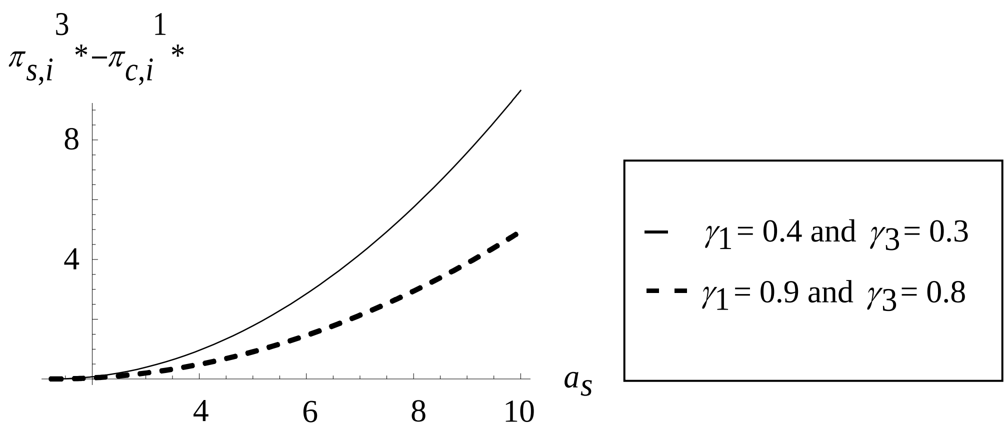

Figure 3.7.2 Profit simulation between stages 1 and 3 for the leader ($\pi_{s,i}^{3*}-\pi_{c,i}^{1*}$) when condition set (b) holds and varying the maximum willingness to pay for a sustainable product (a_s) for two sets of degrees of substitution in stages 1 and 3, γ_1 = 0.9 and γ_3 = 0.8, and γ_1 = 0.4 and γ_3 = 0.3.

Next, we will relax the assumption that $\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} = \frac{a_s}{a_c}$ to consider whether the leader should launch a sustainable product or not when relative costs of a sustainable product of both firms are not equal to the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}} = \frac{c_{s,j}}{c_{c,j}} \neq \frac{a_s}{a_c}\right)$.

Proposition 3: 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 sustainable product and move to stage 2 if:

a. $\frac{c_{s,i}}{c_{c,i}} \leq \frac{a_s}{a_c}$, or

b. $\frac{c_{s,i}}{c_{c,i}} > \frac{a_s}{a_c}$, and $a_s > c_{s,i}(1+A)$ or $a_s - c_{s,i} > c_{s,i}A$ where

$$A = 2\sqrt{2}\sqrt{-\frac{(\gamma_1^2-4)^2(\gamma_1^2-2)\left(\frac{1}{y}-\frac{1}{z}\right)^2}{\left((\gamma_1^2-4)^2+\frac{8(\gamma_1^2-2)}{z^2}\right)^2} + \frac{8(\gamma_1^2-2)\left(\frac{1}{y}-\frac{1}{z}\right)}{\left((\gamma_1^2-4)^2+\frac{8(\gamma_1^2-2)}{z^2}\right)z}} > 0,\ y = \frac{c_{s,i}}{c_{c,i}}, \text{ and}$$

$$z = \frac{a_s}{a_c}.$$

Explanation: The intuition for proposition 3a is that it is *not only* that the relative cost of a sustainable product has to be *equal* to its relative maximum willingness to pay to make a leader get higher profit when launching a sustainable product, *but also* the relative cost of a sustainable product is ***less*** than its relative maximum willingness to pay. This is not surprising because the lower relative cost of a sustainable product and the higher its relative maximum willingness to pay result in a higher profit for producing a sustainable product. Therefore, a leader is more willing to launch a sustainable product to get a higher profit when the relative cost of a sustainable product is less than the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}} < \frac{a_s}{a_c}\right)$.

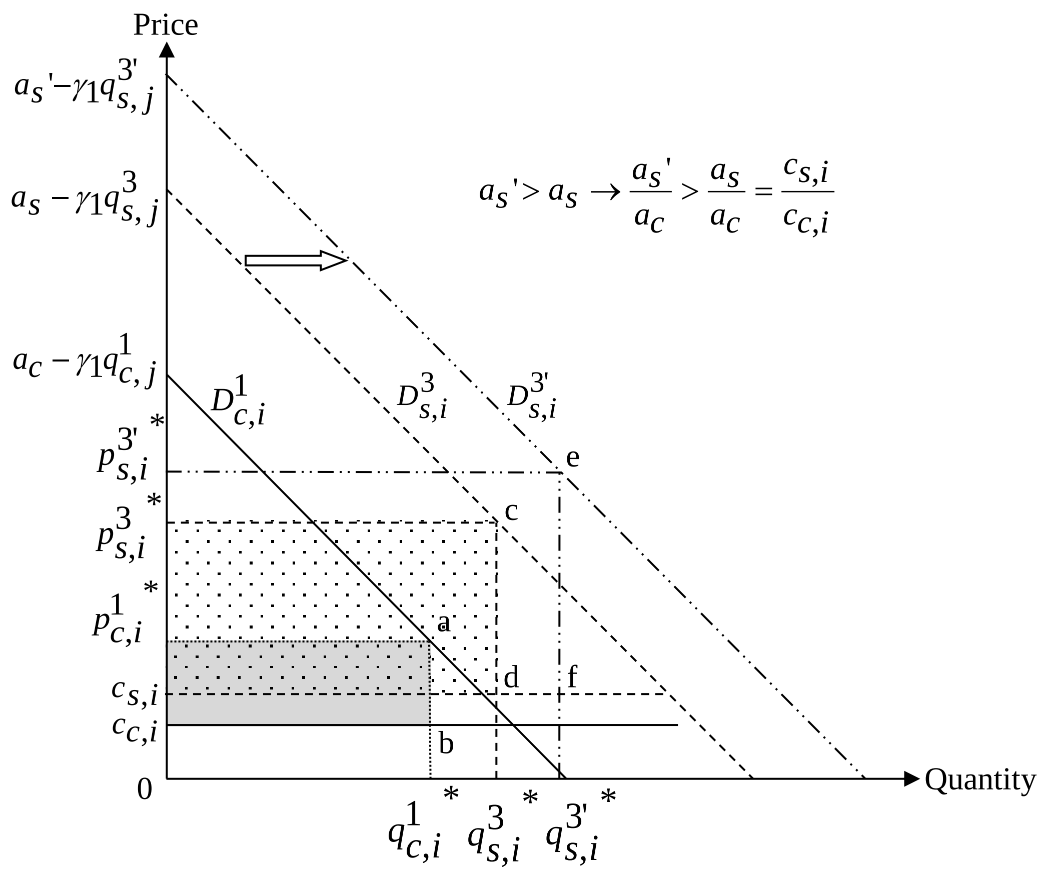

Figure 3.8 Leader's profits in stages 1 and 3 when a relative cost of a sustainable product is less than or equal to the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}} \le \frac{a_s}{a_c}\right)$, degrees of substitution in stages 1 and 3 are the same ($\gamma_1 = \gamma_3$), and firms have the same costs to produce the same types of products ($c_{c,i} = c_{c,j}$ and $c_{s,i} = c_{s,j}$).

Figure 3.8 is an expansion of figure 3.6 where the demand in stage 3 when increasing the maximum willingness to pay for a sustainable product (a_S') has been added. The maximum willingness to pay for a sustainable product increases until the relative cost of a sustainable product is less than its relative maximum willingness to pay $\left(\frac{c_{s,i}}{c_{c,i}} < \frac{a_S'}{a_C}\right)$. When the demand in stage 3 is changed to be $D_{s,i}^{3'}$, the leader's profit in stage 3 increases to be $c_{s,i}$ fe $p_{s,i}^{3'^{*}}$, which is greater than the leader's profit when the demand is $D_{s,i}^{3}$ ($c_{s,i}$ fe $p_{s,i}^{3'^{*}} > c_{s,i}$ dc $p_{s,i}^{3^{*}}$) and certainly greater than the leader's profit in stage 1. Therefore, when a relative cost of a sustainable product is *equal to* or *less* than its relative maximum willingness to pay $\left(\frac{c_{s,i}}{c_{c,i}} \leq \frac{a_S}{a_C}\right)$, the leader decides to launch a sustainable product to get a higher profit.

The intuition for proposition 3b is that even if the relative cost of a sustainable product is higher than its relative maximum willingness to pay, the leader still decides to launch a sustainable product to get a higher profit if the absolute term of maximum willingness to pay for a sustainable product is sufficiently greater than its cost ($a_S > c_{s,i}(1+A)$). That is, proposition 3a focuses on the concept of *relative* terms while proposition 3b focuses on the concept of *absolute* terms.

The constant term A is a function of the degree of substitution (γ), the relative cost of a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}}\right)$, and the relative maximum willingness to pay for a sustainable product $\left(\frac{a_S}{a_C}\right)$. When the degree of substitution increases, the value of term A decreases $\left(\frac{\partial A}{\partial \gamma} < 0\right)$, which makes proposition 3b easier to satisfy; consequently, the leader firm is more likely to launch a sustainable product. Intuitively, the more homogeneous the products, the greater the probability that the leader firm innovates to make a differentiated product to capture higher sale and profit. When the relative cost of a sustainable product increases, the value of term A also increases $\left(\frac{\partial A}{\partial\left(c_{S,i} / c_{C,i}\right)} > 0\right)$, which causes proposition 3b less likely to be satisfied. That is, when the leader has a higher cost to produce the sustainable product compared to the cost of the conventional product, the leader is less likely to launch the sustainable product. Lastly, when the relative maximum willingness to pay for a sustainable product increases, the value of term A decreases $\left(\frac{\partial A}{\partial\left(a_S / a_C\right)} < 0\right)$, which results in proposition 3b becoming easier to satisfy. That is, it is more attractive for the leader to launch the sustainable product when consumers would like to pay more for the sustainable product compared to the amount paid for the conventional product.

To test that proposition 3b is a rare case or not, we use data from the egg industry: $c_{C,i}$ = 0.745, and we assume a_S= 5 and $\gamma_1 = \gamma_3$ = 0.9 (case 1 in table 3.2). Given the maximum willingness to pay for a sustainable product is double the maximum willingness to pay for a conventional product $\left(\frac{a_S}{a_C} = 2\right)$, even the cost of a sustainable product is quadruple the conventional cost $\left(\frac{c_{S,i}}{c_{C,i}} = 4.43\right)$, the leader profits are higher when launching a sustainable egg. Therefore, proposition 3b is also important to the leader's decision making and is not a rare case.

More simulations are shown in table 3.2 when varying the relative maximum willingness to pay for a sustainable product $\left(\frac{a_S}{a_C}\right)$. In addition, from table 3.2, the degrees of substitution ($\gamma_1 = \gamma_3$) are changed in case 2, and the maximum willingness to pay for a sustainable product (a_S) are changed in case 3.

Table 3.2 The egg industry simulations to test whether proposition 3b is a rare case or not when varying the degree of substitution ($\gamma_1 = \gamma_3$), maximum willingness to pay for a sustainable product (a_S), and the relative maximum willingness to pay for a sustainable product $\left(\frac{a_S}{a_C}\right)$.

Case	$\gamma_1 = \gamma_3$	a_S	$\frac{a_S}{a_C}$	The highest value of $\frac{c_{S,i}}{c_{C,i}}$ that the leader still gets a higher profit when launching a sustainable product
1	0.9	5	1.11	1.84
	0.9	5	**2.00**	**4.43**
	0.9	5	5.00	6.38
2	*0.5*	5	1.11	1.68
	0.5	5	2.00	4.36
	0.5	5	5.00	6.37
3	0.9	*10*	1.11	2.70
	0.9	*10*	2.00	7.89
	0.9	*10*	5.00	11.79

Figure 3.9 shows the simulation results of the egg industry when the degree of substitution in stages 1 and 3 are the same and equal to 0.8 ($\gamma_1 = \gamma_3$ = 0.8) for the relationship between the leader's difference in profits ($\pi_{S,i}^{3*} - \pi_{C,i}^{1*}$) and the maximum willingness to pay for a sustainable product (a_S). When the relative cost of a sustainable product is less than or equal to the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{S,i}}{c_{C,i}} \le \frac{a_S}{a_C}\right)$, the

leader's profit in stage 3 is always higher than the leader's profit in stage 1 (all dashed lines have positive values of $\pi_{s,i}^{3}{}^{*} - \pi_{c,i}^{1}{}^{*}$), which is consistent with proposition 3a. When $\frac{c_{s,i}}{c_{c,i}} - \frac{a_s}{a_c}$ is high enough, i.e. $\frac{c_{s,i}}{c_{c,i}}$ = 1.66 (the worst case scenario) and $\frac{a_s}{a_c}$ = 1.1 as in figure 3.9, the leader does not decide to launch a sustainable product when the maximum willingness to pay for a sustainable product (a_s) is a low value (less than 4.70 in Figure 3.9) since the leader gets a lower profit when launching a sustainable product. Moreover, the higher value of the maximum willingness to pay for a sustainable product ($a_s \uparrow$), the greater the probability that the leader will get a higher profit when launching a sustainable product ($\pi_{s,i}^{3}{}^{*} - \pi_{c,i}^{1}{}^{*} \uparrow$), which is consistent with proposition 3b.

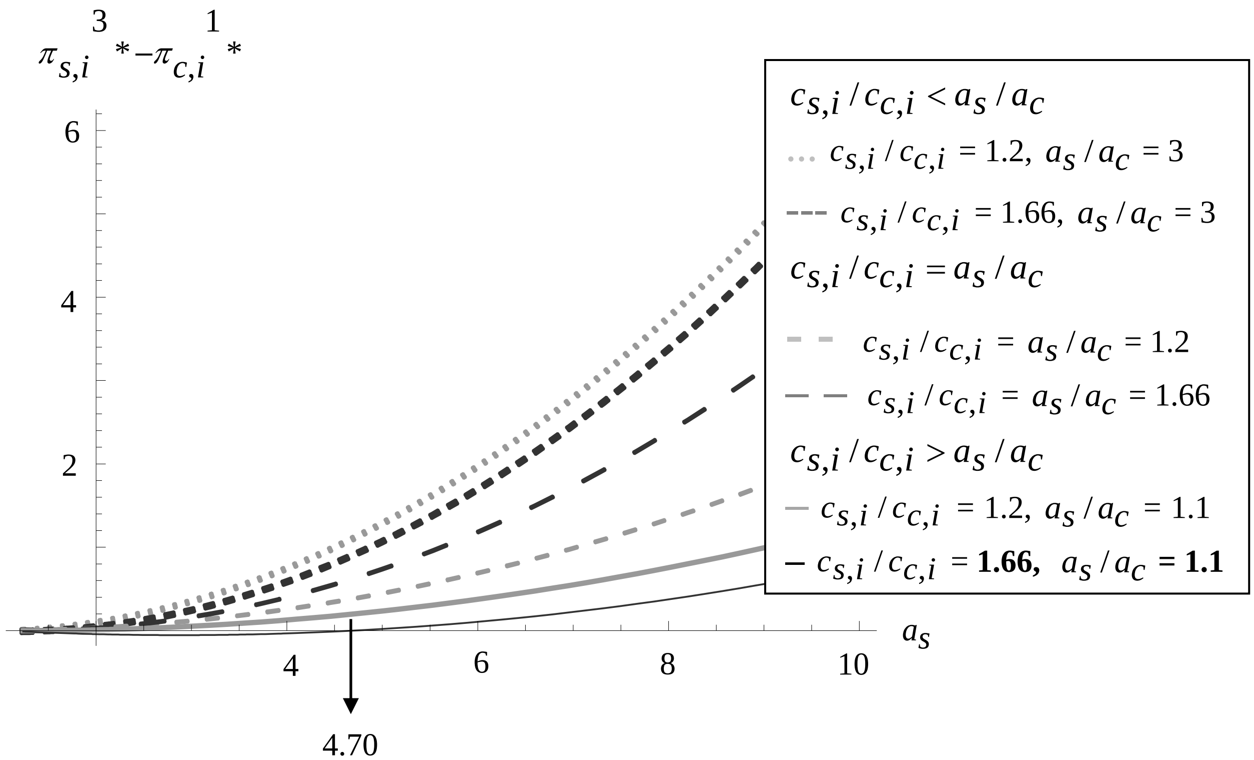

Figure 3.9 Profit simulation between stages 1 and 3 for the leader ($\pi_{s,i}^{3}*-\pi_{c,i}^{1}*$) varying the maximum willingness to pay for a sustainable product (a_s) for variety sets of the relative costs of a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}}\right)$ and the relative maximum willingness to pay for a sustainable product $\left(\frac{a_s}{a_c}\right)$.

Proposition 4 explores when the leader assumes that *the follower will not launch* a sustainable product later. When the leader expects that the follower will not launch a sustainable product later, the leader will compare its profits in stages 1 and 2 for the decision making to launch a sustainable product.

Proposition 4: When $\gamma_1 = \gamma_2^c = \gamma_2^s$, and $c_{c,i} = c_{c,j}$, the leader will decide to launch a sustainable product and move to stage 2 if:

a. $\frac{c_{s,i}}{c_{c,i}} \le \frac{a_s}{a_c}$, or

b. $\frac{c_{s,i}}{c_{c,i}} > \frac{a_s}{a_c}$ and $a_s - c_{s,i} > a_c - c_{c,i}$.

Explanation: Proposition 4 shows that the leader should launch a sustainable product when the relative cost of a sustainable product is less than or equal to its relative maximum willingness to pay $\left(\frac{c_{s,i}}{c_{c,i}} \le \frac{a_s}{a_c}\right)$, or the additional cost to produce a sustainable product can be covered by the additional maximum willingness to pay for a sustainable product. If the concept of relative does not hold in proposition 4a $\left(\frac{c_{s,i}}{c_{c,i}} > \frac{a_s}{a_c}\right)$, then the leader still decides to launch a sustainable product to obtain a higher profit when the difference between the maximum willingness to pay for a sustainable product and its cost is sufficiently high ($a_s - c_{s,i} > a_c - c_{c,i}$). That is, if the *relative* term concept does not hold, the leader still decides to launch a sustainable product if the *absolute* term concept holds. Hence, proposition 4 has the similar intuition as proposition 3. Proposition 4b is not a rare case as shown in table 3.3. For example, when the maximum willingness to pay for a conventional product (a_s) equals 5 (case 1 in table 3.3), even when the maximum willingness to pay for a sustainable product is double the conventional product $\left(\frac{a_s}{a_c} = 2\right)$, the relative cost of a sustainable product can be as high as 4.36 $\left(\frac{c_{s,i}}{c_{c,i}} = 4.36\right)$. More simulations when varying the relative maximum willingness to pay for a sustainable product $\left(\frac{a_S}{a_C}\right)$ are shown in table 3.3. The maximum willingness to pay for a sustainable product ranged from 5 to10 in case 2 to test the robustness of the model.

Table 3.3 The egg industry simulation to test whether proposition 4b is a rare case or not when varying the value of the relative maximum willingness to pay for a sustainable product $\left(\frac{a_S}{a_C}\right)$, and the maximum willingness to pay for a sustainable product (a_S).

Case	a_S	$\frac{a_S}{a_C}$	The highest value of $\frac{c_{S,i}}{c_{C,i}}$ that the leader still gets a higher profit when launching a sustainable product
1	5	1.11	1.67
	5	**2.00**	**4.36**
	5	10.00	6.37
2	*10*	1.11	2.34
	10	2.00	7.71
	10	10.00	11.74

Figure 3.10 shows the relationship between the leader's difference in profits in stages 1 and 2 ($\pi_{S,i}^{2}* - \pi_{C,i}^{1}*$) and the difference between the maximum willingness to pay for a sustainable product and the cost of a sustainable product ($a_S - c_{S,i}$), which is consistent with proposition 4. That is, when $\left(\frac{c_{S,i}}{c_{C,i}} \leq \frac{a_S}{a_C}\right)$, the leader's profit in stage 2 is always higher than the leader's profit in stage 1 (all dashed lines have positive values of $\pi_{S,i}^{2}* - \pi_{C,i}^{1}*$). Moreover, when assuming the relative cost of a sustainable product is higher than its relative maximum willingness to pay $\left(\frac{c_{S,i}}{c_{C,i}} > \frac{a_S}{a_C}\right)$, the higher value of $a_S - c_{S,i}$, the higher probability that

$\pi_{s,i}^{2}*$ is greater than $\pi_{c,i}^{1}*$. For example, when determining $c_{c,j}$ = 0.75, $\frac{c_{s,i}}{c_{c,i}}$ = 1.66 (the worst case scenario), $\frac{a_s}{a_c}$ =1.1, and degrees of substitution in stages 1 and 2 are the same and equal to 0.9 ($\gamma_1 = \gamma_2^c = \gamma_2^s$ = 0.9), the leader's difference in profits in stages 1 and 2 ($\pi_{s,i}^{2}* - \pi_{c,i}^{1}*$) can be negative or positive. It will be a positive value when the difference between the maximum willingness to pay for a sustainable product and the cost of a sustainable product ($a_s - c_{s,i}$) is sufficiently high ($a_s - c_{s,i}$ > 4.17), which is consistent with proposition 4b.

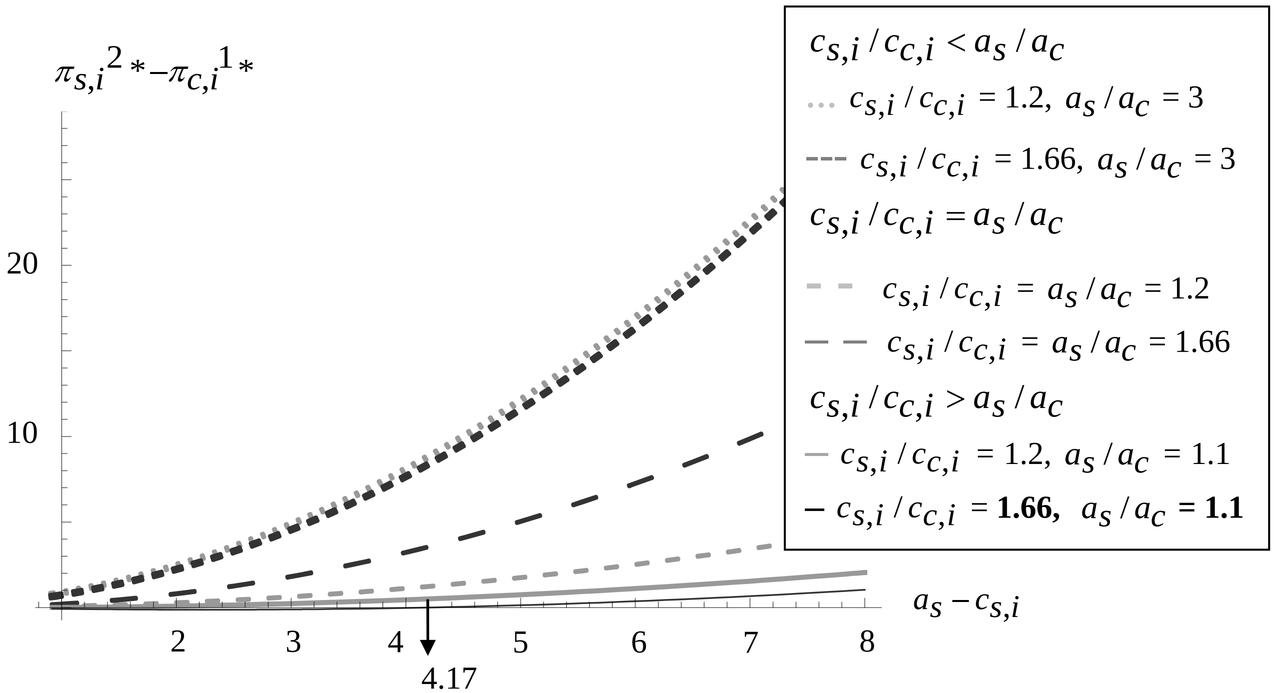

Figure 3.10 Profit simulation between stages 1 and 2 for the leader ($\pi_{s,i}{}^{2}* - \pi_{c,i}{}^{1}*$) varying the difference between the maximum willingness to pay for a sustainable product and the cost of a sustainable product ($a_s - c_{s,i}$) for a variety of relative cost $\left(\frac{c_{s,i}}{c_{c,i}}\right)$ and relative maximum willingness to pay $\left(\frac{a_s}{a_c}\right)$.

Consider the egg industry situation, proposition 1, and the simulation results from section 3.6.1.1, the follower's launch decision making is known: the follower decided to launch after the leader has launched. Hence, in this step, the leader makes a launch decision given the information that the follower decided to launch a sustainable egg ($\pi_{s,j}{}^{3}* > \pi_{c,j}{}^{2}*$); thus, the leader compares its profits in stages 1 and 3. Proposition 3 considers the leader's decision making[29]. The first step to do that is to check whether proposition 3a holds. Figures 3.11.1 and 3.11.2 show values of $\frac{c_{s,i}}{c_{c,i}}$ and $\frac{a_s}{a_c}$ for the worst case and the best case from the simulations when γ is varied (Note, $\frac{a_s}{a_c}$, and γ are not directly observed). Figure 3.11.1 shows that proposition 3a does not hold for the worst case for all values of γ since $\frac{c_s}{c_c}$ is greater than $\frac{a_s}{a_c}$ while figure 3.11.2 shows that proposition 3a holds for the best case when γ is low (γ is less than 0.88).

[29] The reasons are: 1) proposition 3 compares the leader's profits in stages 1 and 3, and 2) proposition 3 does *not* require the equality of the relative cost of a sustainable product and the relative maximum willingness to pay for a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}} \neq \frac{a_s}{a_c}\right)$, which is flexible and appropriate to use in our analysis.

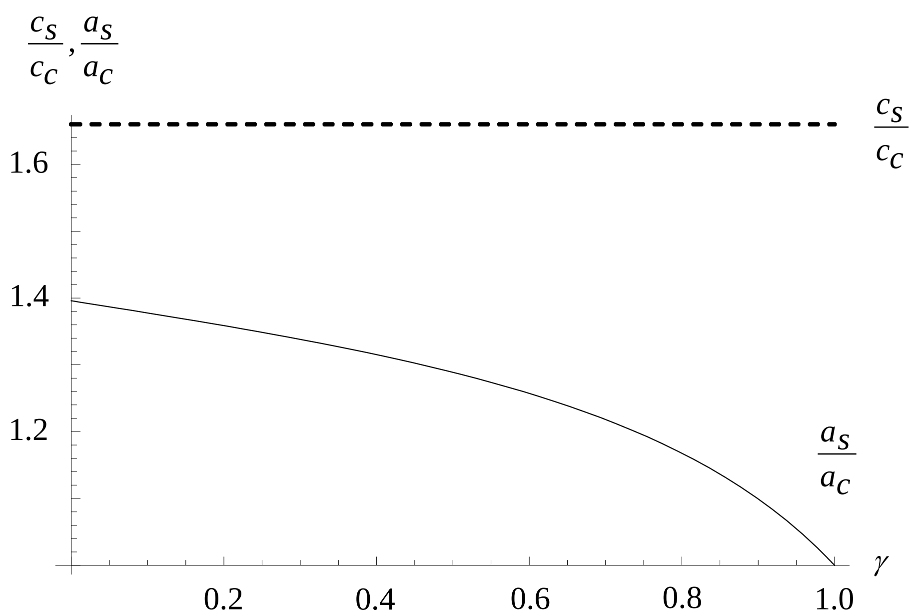

Figure 3.11.1 The relationship between $\frac{c_S}{c_C}$ or $\frac{a_S}{a_C}$ and γ for *the worst case scenario.*

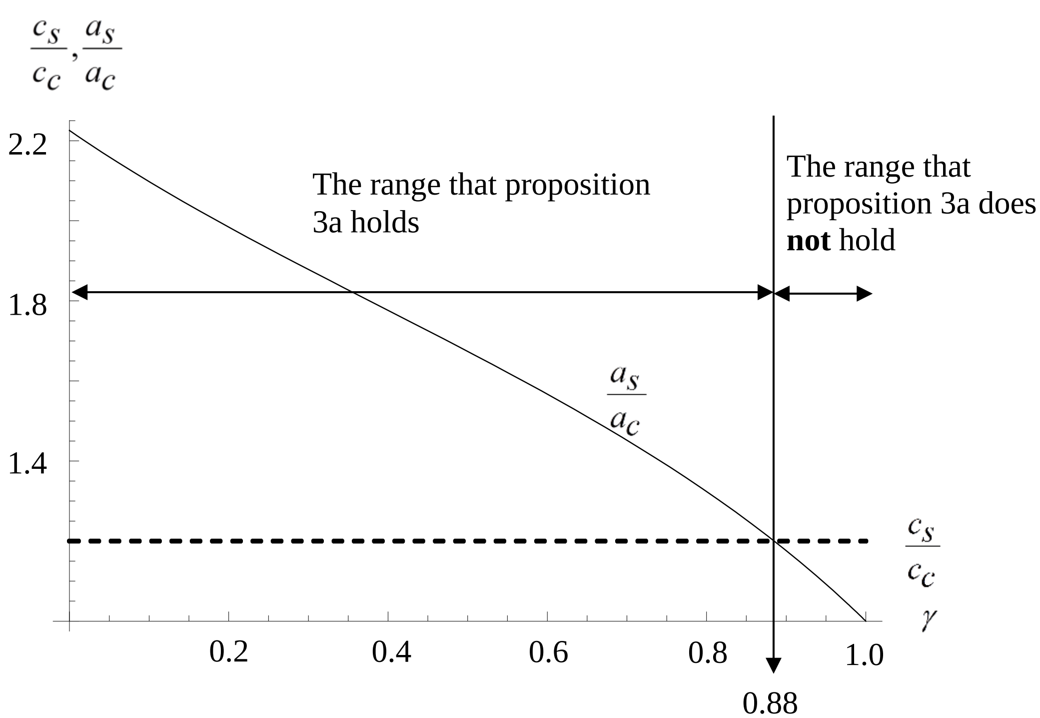

Figure 3.11.2 The relationship between $\frac{c_S}{c_C}$ or $\frac{a_S}{a_C}$ and γ for *the best case scenario.*

Since proposition 3a does not hold in general, we check whether proposition 3b holds. Figures 3.12.1 and 3.12.2 show that proposition 3b holds for both the worst and the best case since the values of $a_S - c_{S,i}$ are greater than $c_{S,i}A$ for all γ. Consequently, the leader's profit in stage 3 ($\pi_{s,i}^{3}*$) is higher than the leader's profit in stage 1 ($\pi_{c,i}^{1}$); therefore, **the leader decides to launch the sustainable egg into the market**[30].

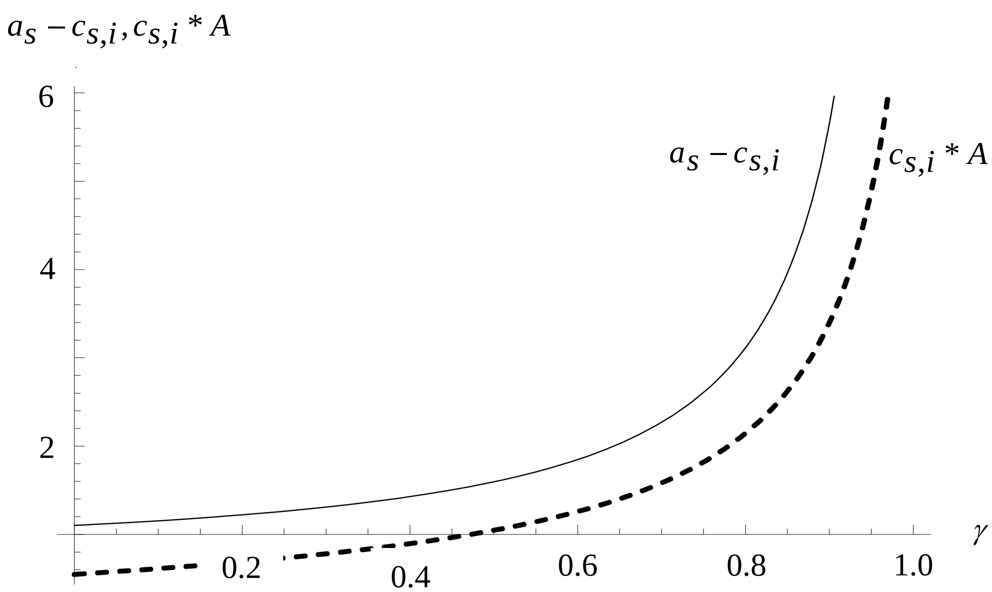

Figure 3.12.1 The relationship between $a_S - c_{S,i}$ or $c_{S,i} * A$ and γ for *the worst case scenario.*

[30] The leader's equilibrium price of a sustainable egg in stage 3 is greater than the leader's equilibrium price of a conventional product in stage 1 ($p_{s,i}^{3}* > p_{c,i}^{1}*$) while the leader's equilibrium quantity in stage 3 is not necessarily greater than the leader's equilibrium quantity in stage 1. That is, the equilibrium quantity in stage 3 is greater than the equilibrium quantity in stage 1 ($q_{s,i}^{3}* > q_{c,i}^{1}*$) when consumers realize the difference between conventional and sustainable eggs enough or when γ is less than 0.57 for the worst case and 0.86 for the best case scenario.

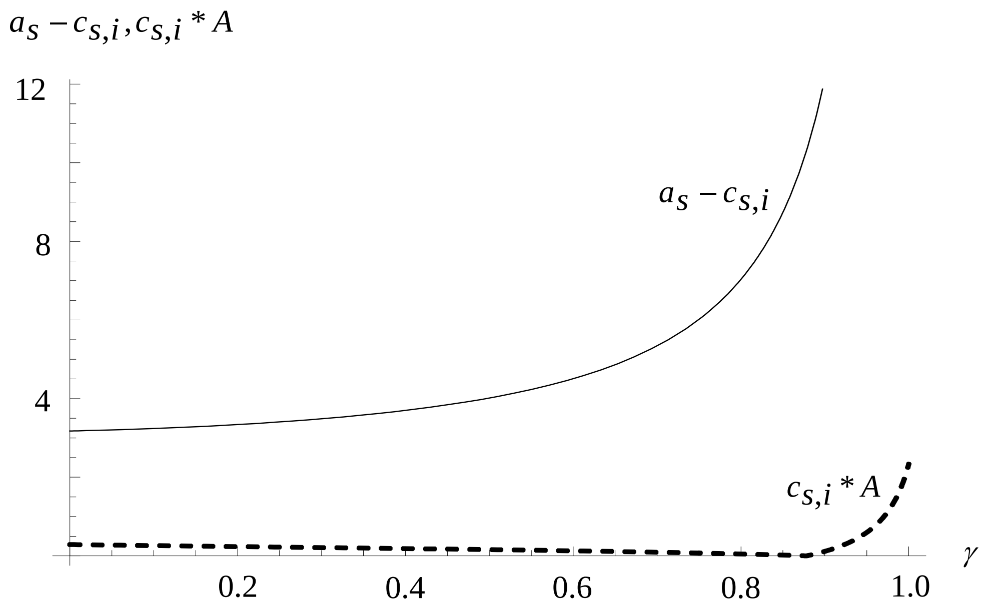

Figure 3.12.2 The relationship between $a_S - c_{S,i}$ or $c_{S,i} * A$ and γ for *the best case scenario.*

In sum, according to the prices and costs of the conventional and the sustainable eggs from the literature, **both the leader and the follower egg manufacturers should launch a sustainable egg product to get higher profits**. This corresponds with what we observe, there is an expansion of the sustainable egg market during the past few years, even store brands have launched cage-free and/or free-range eggs in many regions of the U.S (Patterson 2011).

After determining the conditions that firms should launch sustainable products to get a higher profit, the conditions that encourage a firm to be a leader firm are explored.

3.6.2 Conditions that encourage a firm to be a leader

This part starts with the standard findings and propositions from comparing profits of both firms in each stage. Simulations of the egg industry are used to explain the intuition and make the standard findings and propositions more understandable. The study concludes with the conditions that encourage a firm to be a leader to launch a sustainable product to the market.

3.6.2.1 Comparison of profits in stage 1

Standard Finding 1: In **stage 1**, marginal costs[31] determine which firm has a higher profit. Moreover, the difference in marginal costs and the degree of substitution (γ_1) determines the amount of difference in profits. The larger the difference in marginal costs, and/or the larger degree of substitution lead(s) to a larger difference in profits.

Explanation: Since γ_1 is symmetrical for both inverse demand functions in stage 1 ($p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j}$, and $p_{c,j} = a_c - q_{c,j} - \gamma_1 q_{c,i}$), both firms face the same demand function. Therefore, the firm who has a lower marginal cost will achieve a higher profit. Consumers can easily switch to the cheaper product when the degree of substitution (γ_1) is high meaning the two products are similar.

The egg industry sheds light on the relationships between the two firms in stage 1. The first simulation assumes[32] that a_c = 3.01 when $\frac{c_{c,i}}{c_{c,j}}$ equals 1, the marginal cost for both

[31] In our analysis, the marginal costs are the same as the variable costs.
[32] We assume a_c = 3.01 to be consistent with the demand for eggs/person/10 weeks. The details are shown in footnote 25.

conventional goods are the same, and when $\frac{c_{c,i}}{c_{c,j}}$ is less (more) than 1, $c_{c,i}$ is less (more) than $c_{c,j}$, figures 3.13.1 and 3.13.2 are obtained. Figure 3.13.1 shows that when the marginal cost of firm i is lower (higher) than the marginal cost of firm j or $\frac{c_{c,i}}{c_{c,j}} < 1$ ($\frac{c_{c,i}}{c_{c,j}} > 1$), 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 3.13.2, when the degree of substitution (γ_1) changes, the sign of the difference in profits of the 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.

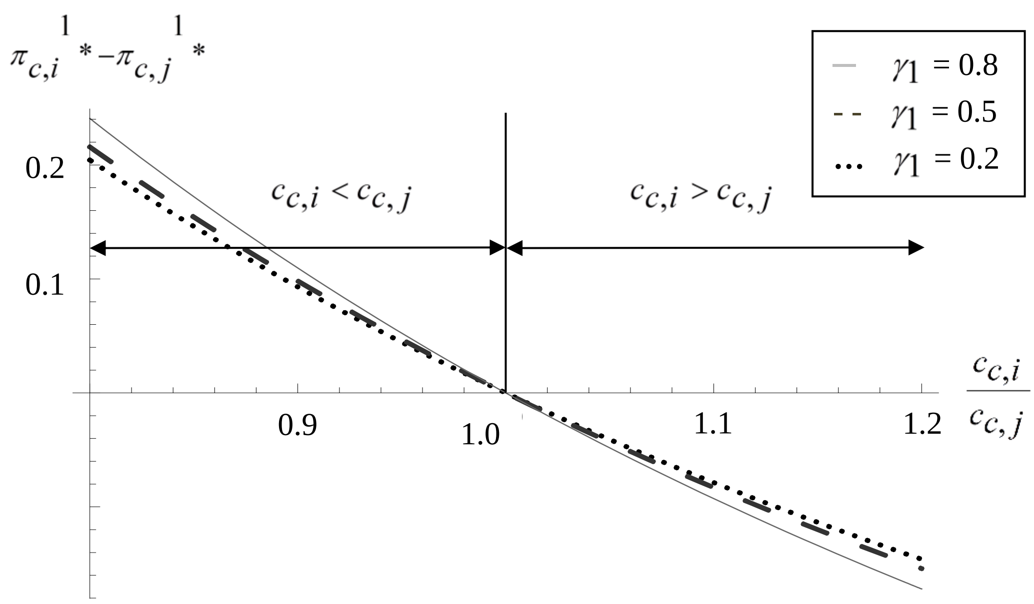

Figure 3.13.1 Profit simulation between two firms in stage 1 varying the relative cost $\left(\frac{c_{c,i}}{c_{c,j}}\right)$ for three levels of degree of substitution in stage 1 (γ_1), 0.8, 0.5, and 0.2.

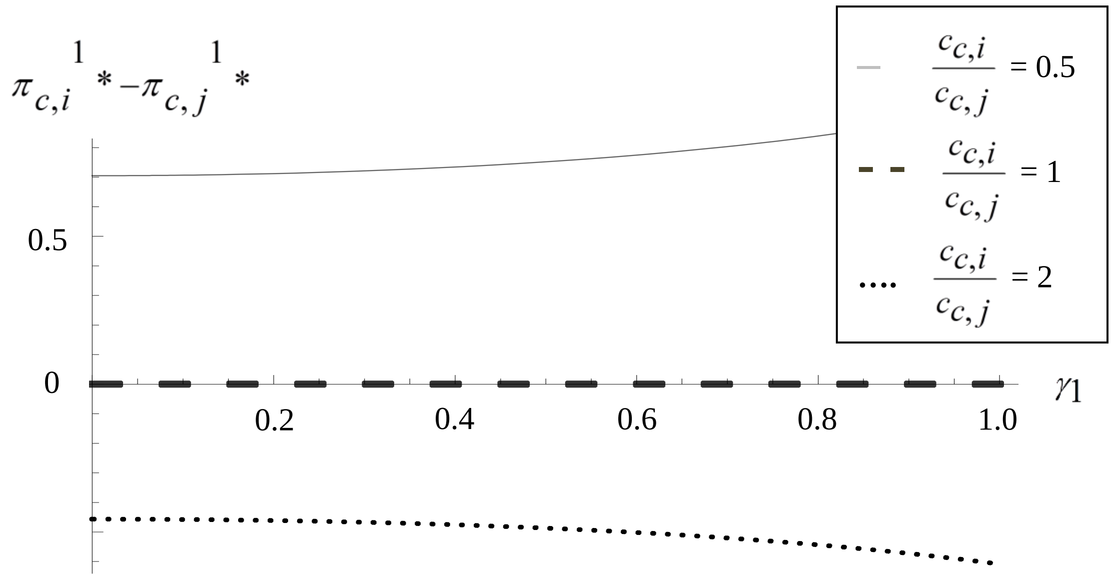

Figure 3.13.2: Profit simulation between two firms in stage 1 varying the degree of substitution in stage 1 (γ_1) for the three levels of the relative cost $\left(\frac{c_{c,i}}{c_{c,j}}\right)$, 0.5, 1, and 2.

3.6.2.2 Comparison of profits in stage 2

Standard Finding 2: When the degree of substitution of a conventional and sustainable product are the same in **stage 2** ($\gamma_2^c = \gamma_2^s$), and the levels of maximum willingness to pay for two types of products are the same ($a_s = a_c$), ***the firm that produces a conventional product will have a higher profit than the firm that produces a sustainable product***.

Explanation: A firm that produces a sustainable product has a higher cost than a firm which produces a conventional product ($c_{s,i} > c_{c,j}$). However, consumers do not realize the difference between the two types of products ($\gamma_2^c = \gamma_2^s$) and would like to pay the same amount for both types ($a_S = a_C$). Consequently, the firm that produces a conventional product gets a higher profit than the firm that launches a sustainable product in this stage.

Next, the restrictions $\gamma_2^C = \gamma_2^S$ and $a_S = a_C$ are relaxed in order to compare the profits of two firms in stage 2 in the general case.

Proposition 5: In **stage 2**, the firm that launches a sustainable product will get a higher profit than the profit of the firm that produces a conventional product if:

a. $\frac{c_{S,i}}{c_{C,j}} \le \frac{a_S}{a_C}$, or

b. $\frac{c_{S,i}}{c_{C,j}} > \frac{a_S}{a_C}$, and $\frac{a_S}{c_{S,i}} > B$

where $B = \frac{z\left(\gamma_2^C(1 - xy + \gamma_2^C(y-1)) - 2x(y-1)\right)}{y\left(\gamma_2^C(1 - xz + \gamma_2^C(z-1)) - 2x(z-1)\right)}$, $x = \frac{\gamma_2^C}{\gamma_2^S}$, $y = \frac{c_{S,i}}{c_{C,j}}$, and $z = \frac{a_S}{a_C}$.

Explanation: The intuition of this proposition is similar to the intuition of proposition 3 except proposition 3 compares the profits of the same firm when producing different types of products (different stages) while proposition 5 compares the profits of different firms, which produce different types of products in the same stage. When the relative cost of a sustainable product is less than or equal to its relative maximum willingness to pay, the firm which launches a sustainable product will get a higher profit than the firm that still produces a conventional product (proposition 5a). This implies that the additional cost to produce the sustainable product can be covered by the additional maximum willingness to pay for the sustainable product.

However, when proposition 5a does not hold, the firm that launches a sustainable product still obtains a higher profit than the firm which produces a conventional product if the maximum willingness to pay over the cost of a sustainable product is sufficiently high $\left(\frac{a_s}{c_{s,i}} > B\right)$.

The constant term B is a combination of the degree of substitution of a sustainable product to a conventional product $\left(\gamma_2^c\right)$, the relative degree of substitution ($\frac{\gamma_2^c}{\gamma_2^s}$), the relative cost of a sustainable product $\left(\frac{c_{s,i}}{c_{c,i}}\right)$, and the relative maximum willingness to pay for a sustainable product $\left(\frac{a_s}{a_c}\right)$. When the sustainable product is substituted for the conventional product to a higher degree, the value of constant term B decreases $\left(\frac{\partial B}{\partial \gamma_2^c} < 0\right)$, which makes proposition 5b easier to satisfy. Intuitively, when the sustainable product is more substitutable for the conventional product, consumers are more likely to purchase the sustainable product, which causes the demand for the sustainable product to increase. Hence, the leader is more likely to get a higher profit than the follower in stage 2. Similarly, when the relative degree of substitution increases, the value of term B decreases $\left(\frac{\partial B}{\partial\left(\gamma_2^c / \gamma_2^s\right)} < 0\right)$. This results in the relative demand for the sustainable product over the conventional product to increase making the leader more likely to receive a higher profit than the follower in stage 2. Next, when the relative cost of the sustainable product increases, the value of term B increases $\left(\frac{\partial B}{\partial\left(c_{s,i}/c_{c,j}\right)} > 0\right)$, and it is more difficult for proposition 5b to be satisfied. It is not surprising that the leader who launches the sustainable product is less likely to have more profit than the follower if the relative cost of a sustainable product increases. Lastly, when the relative maximum willingness to pay for the sustainable product increases, the value of term B decreases $\left(\frac{\partial B}{\partial\left(a_s/a_c\right)} < 0\right)$, which makes proposition 5b more likely to be satisfied. That is, when consumers would like to pay more for the sustainable product compared to the conventional product, the leader firm who markets the sustainable product is more likely to have a higher profit than a profit of the follower firm who markets the conventional product in stage 2.

In addition, proposition 5b is not a rare case as shown in table 3.4. Assuming $c_{c,j}$ = 0.745, a_s = 5, γ_2^c = 0.9, and $\frac{\gamma_2^s}{\gamma_2^c}$ = 0.9 (case 2 in table 3.4), the cost of the sustainable product can be higher than the cost of the conventional product by 4.45 times, which makes the leader's profit higher than the follower's profit in stage 2. Table 3.4 also shows simulations when varying the relative maximum willingness to pay for the sustainable product $\left(\frac{a_s}{a_c}\right)$, and when the relative degree of substitution in stage 2 $\left(\frac{\gamma_2^c}{\gamma_2^s}\right)$ and the degree of substitution of a sustainable product to a conventional product in stage 2 (γ_2^c) are varied (case 1).

Table 3.4 Egg industry simulation of proposition 5b when varying the relative maximum willingness to pay $\left(\frac{a_S}{a_C}\right)$, the relative degree of substitution $\left(\frac{\gamma_2^S}{\gamma_2^C}\right)$, and the degree of substitution in stage 2 (γ_2^C).

Case	$\frac{\gamma_2^S}{\gamma_2^C}$	γ_2^C	$\frac{a_S}{a_C}$ (1)	Highest value of $\frac{c_{S,i}}{c_{C,i}}$ that the sustainable product launching firm gets a higher profit than the profit of the firm which producing a conventional product (2)	$\frac{c_{S,i}}{c_{C,j}} \Big/ \frac{a_S}{a_C}$ or (2)/(1)
1	*0.5*	*0.5*	1.11	2.20	1.98
	0.5	*0.5*	2.00	4.60	2.30
	0.5	*0.5*	5.00	6.40	1.28
2	0.9	0.9	1.11	1.88	1.69
	0.9	**0.9**	**2.00**	**4.45**	**2.23**
	0.9	0.9	5.00	6.38	1.28

Figure 3.14 shows the simulation results for the relationship between the difference in profits of two firms in stage 2 ($\pi_{S,i}{}^{2*} - \pi_{C,j}{}^{2*}$), and the maximum willingness to pay for a sustainable product (a_S) assuming $c_{C,j} = 0.745$, $\gamma_2^C = 0.9$, $\frac{\gamma_2^S}{\gamma_2^C} = 0.9$, and $\frac{a_S}{a_C} = 1.4772$. When the relative cost of a sustainable product is less than or equal to the relative maximum willingness to pay for a sustainable product ($\frac{c_{S,i}}{c_{C,j}} = \frac{1}{2} * \frac{a_S}{a_C}$, and $\frac{c_{S,i}}{c_{C,j}} = \frac{a_S}{a_C}$ in figure 3.14), the profit of the firm that launches a sustainable product is always higher than the profit of the firm that produces a conventional product, which represents proposition 5a. When the relative cost of

a sustainable product is higher than the relative maximum willingness to pay for a sustainable product ($\frac{c_{s,i}}{c_{c,j}} = 3 * \frac{a_s}{a_c}$, and $\frac{c_{s,i}}{c_{c,j}} = 5 * \frac{a_s}{a_c}$ in figure 3.14), whether the profit of the firm that launches a sustainable product is higher than the profit of the firm which produces a conventional product or not depends on the value of maximum willingness to pay for a sustainable product (proposition 5b). That is, the higher value of the maximum willingness to pay for the sustainable product, the more likely that the firm launching the sustainable product gets higher profits.

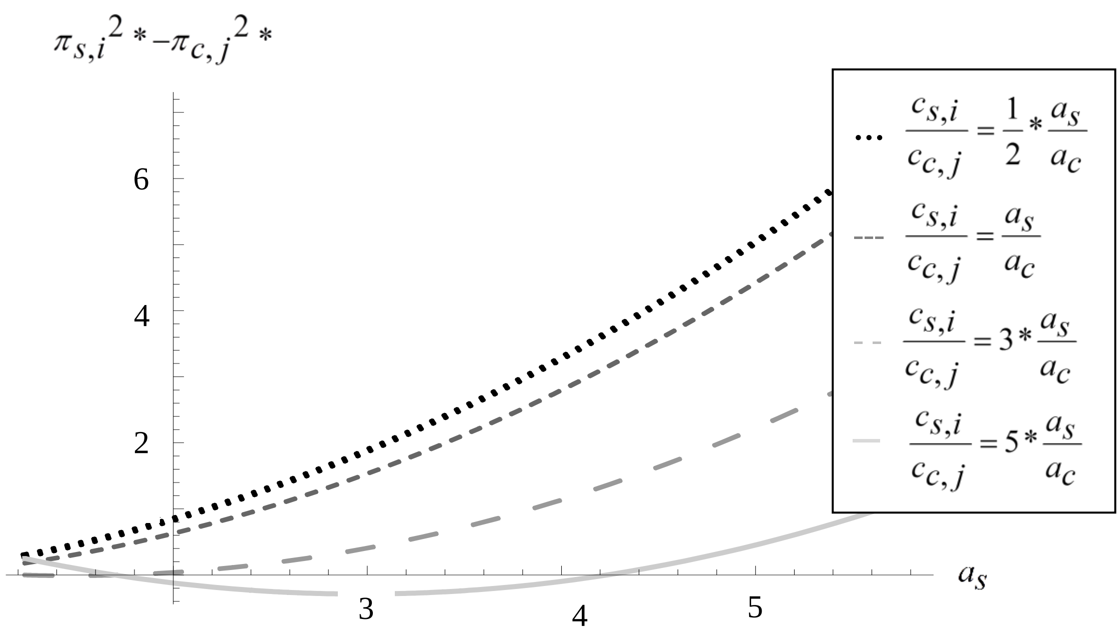

Figure 3.14 Profit simulation between two firms in stage 2 ($\pi_{s,i}^{2*} - \pi_{c,j}^{2*}$) varying the maximum willingness to pay (a_s) for variety of relative costs $\left(\frac{c_{s,i}}{c_{c,i}}\right)$ and the relative maximum willingness to pay $\left(\frac{a_s}{a_c}\right)$.

3.6.2.3 Comparison of profits in stage 3

Standard Finding 3: In **stage 3**, when both firms have the same (marginal) cost ($c_{S,i} = c_{S,j}$), ***the follower firm 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).

Explanation**:** Under the Stackelberg price leadership model, the leader sets the price first, and the follower sets its price after observing the price in the new market. Under the same marginal cost, the follower will undercut the price of the leader in order to get a higher market share and a higher profit. In the Stackelberg price leadership model, the follower gets a second-mover advantage in the sense that the follower has more information about the leader's price and can set their price accordingly.

From the comparisons of profits of the two firms in each stage, it can be concluded that there are three factors that encourage a firm to be a leader. First, if a firm has a *disadvantage* in cost to produce a conventional product, a firm has an incentive to switch to produce and market a sustainable product. This is because a firm can increase its market share and profit by launching a sustainable product instead of producing a conventional product, which is dominated by another firm who has a lower cost. Second, a firm would like to launch a sustainable product first to get a higher profit if the relative cost of the sustainable product is less than or equal to its relative maximum willingness to pay. That is, when the consumers demand is strong for the sustainable product while the cost of the sustainable product is not too high, the probability of the leader launching is higher in stage 2. Lastly, a cost *advantage* for producing a sustainable product encourages a firm to be a leader by launching first. If a leader firm has the same or higher production cost for the sustainable product than the follower, the leader firm will lose the market share, and has less profit than the follower when the follower also switches to market a sustainable product. This is because the follower can observe the leader's sustainable product price and then undercut the price to get higher quantity, market share, and profit. Thus, if a firm has a cost disadvantage for producing a sustainable product, it is better to wait to launch a sustainable product later to get a higher profit.

Figure 3.15 is a flow chart that summarizes the relationship of all propositions, standard findings, and their restrictions. The boxes named stage 1, stage 2, and stage 3 show the findings from the comparisons of the profits of two firms in stages 1, 2, and 3, respectively. The shaded boxes show the propositions and their restrictions regarding the movement to the next stage. There are two sets of boxes that contain the propositions and their restrictions regarding moving to stage 2. This implies that there are two separate ways to move to stage 2: 1) comparing the leader's profits in stages 1 and 2, and 2) comparing the leader's profits in stages 1 and 3. For the left path, we compare the leader's profits in stages 1 and 2 when the follower will decide not to launch the sustainable product; hence, the boxes on the left hand side show the progression to stage 2. For the right path, we compare the leader's profits in stages 1 and 3 when the follower will decide to launch the sustainable product, so the boxes on the right hand side show the move to stage 3.

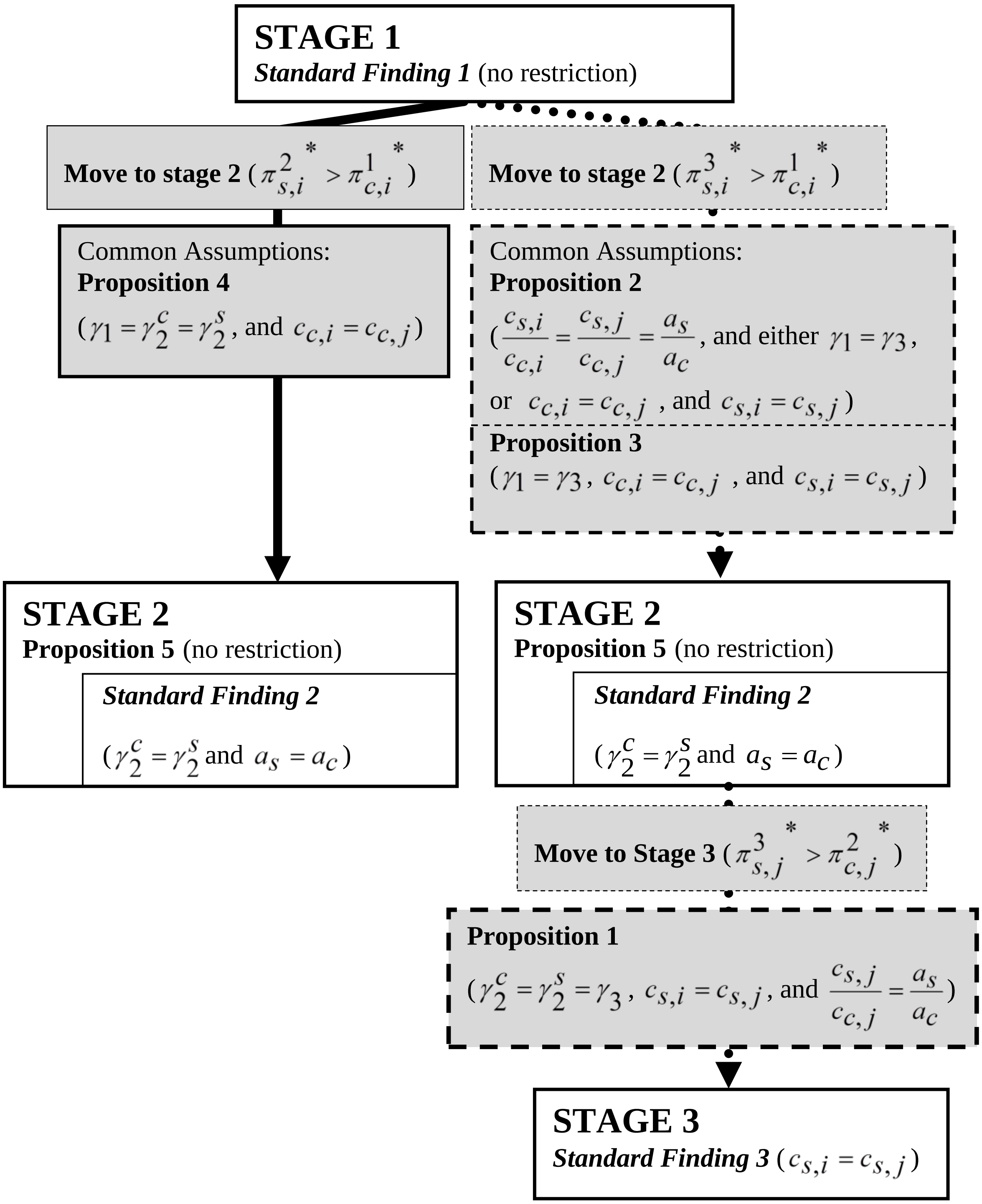

Figure 3.15 Summary of decision making arranged by propositions, standard findings, and their restrictions.

3.7 Conclusion

A food manufactures' decision making model is constructed to illustrate the launching strategy of a sustainable food product. The factors that influence firms to launch a sustainable product are from both demand and supply side. That is, on the demand side, food manufacturers decide to launch a sustainable product when consumers realize and prefer the difference between the conventional and the sustainable products; moreover, they prefer and are willing to pay more for the sustainable product. On the supply side, the firms get higher profits when launching the sustainable product if the relative cost of the sustainable product is low enough; that is less than or equal to the relative maximum willingness to pay for the sustainable product. This implies that the additional cost to produce the sustainable product has to be covered by the additional maximum willingness to pay for the sustainable product to induce the firms to launch the sustainable product.

The study also determines the conditions that encourage a firm to be a leader. A firm decides to be a leader when it has a cost disadvantage in producing a conventional product, but has a cost advantage to producing a sustainable product. Moreover, the firm decides to be a leader when the relative cost of the sustainable product has to be less than or equal to its relative maximum willingness to pay, which is the same condition that encourages the firm to launch the sustainable product.

The leader firm and the follower firm have different criterion to launch a sustainable product. On one hand, the leader firm has to determine first whether the relative maximum willingness to pay for the sustainable product is higher than the relative cost of the sustainable product (the relative term concept), and the leader firm decides to launch the sustainable product and attains a higher profit when this relative condition holds. If not, the leader has to determine whether the absolute value of the maximum willingness to pay for the sustainable product is sufficiently higher than the absolute value of the cost of the sustainable product or not, and decides to launch when the absolute concept holds. On the other hand, the follower's most influential factor is the degree of substitution; consumers have to realize the difference between the sustainable and conventional product. If the consumers perceive the two products to be close but not the same, then the follower firm will decide to produce a me too product only when the costs of productions of the two goods are sufficiently close. In addition, the simulation results show that egg manufacturers, both the leader and the follower firms, should launch sustainable egg products to get higher profits. As a consequence, both national and store brand manufacturers have increasingly marketed sustainable eggs the past few years.

APPENDICES

APPENDIX B: PROFIT DERIVATION BY STAGE

Stage 1:

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

$$p_{c,i} = a_c - q_{c,i} - \gamma_1 q_{c,j}\text{, and} \tag{3.1}$$

$$p_{c,j} = a_c - q_{c,j} - \gamma_1 q_{c,i}\,. \tag{3.2}$$

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 for firm i and firm j , respectively. The first order condition (FOC) is then:

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

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

We also check the second order condition (SOC) which is $\dfrac{\partial^2 \pi_i}{\partial p_{c,i}{}^2} = \dfrac{2}{(\gamma_1)^2 - 1} < 0$. This confirms a maximum. Rearranging and with some substitutions, the reaction functions are:

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

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

From solving (B.1) and (B.2) simultaneously, we get the optimal prices in stage 1 ($p_{c,i}{}^{1}*$, and $p_{c,j}{}^{1}*$) as follows:

$$p_{c,i}{}^{1}* = \left(\frac{\left(2-\gamma_1-(\gamma_1)^2\right)a_c + \gamma_1 c_{c,j} + 2c_{c,i}}{\left(4-(\gamma_1)^2\right)}\right), \text{ and} \tag{B.3}$$

$$p_{c,j}{}^{1}* = \left(\frac{\left(2-\gamma_1-(\gamma_1)^2\right)a_c + \gamma_1 c_{c,i} + 2c_{c,j}}{\left(4-(\gamma_1)^2\right)}\right). \tag{B.4}$$

By plugging the equilibrium prices into the demand functions, the equilibrium quantities in stage 1 ($q_{c,i}{}^{1}*$, and $q_{c,j}{}^{1}*$) are as follows:

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

$$q_{c,j}{}^{1}* = \frac{(2-\gamma_1-\gamma_1^2)a_c + \gamma_1 c_{c,i} + (\gamma_1^2-2)c_{c,j}}{4-5\gamma_1^2+\gamma_1^4}. \tag{B.6}$$

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

$$\pi_{c,i}^{1}* = \frac{\left[a_c\left(2-\gamma_1-\gamma_1^2\right)-\left(2-\gamma_1^2\right)c_{c,i}+\gamma_1 c_{c,j}\right]^2}{\left(\gamma_1^2-4\right)^2\left(1-\gamma_1^2\right)}, \text{ and} \quad \text{(B.7)}$$

$$\pi_{c,j}^{1}* = \frac{\left[a_c\left(2-\gamma_1-\gamma_1^2\right)-\left(2-\gamma_1^2\right)c_{c,j}+\gamma_1 c_{c,i}\right]^2}{\left(\gamma_1^2-4\right)^2\left(1-\gamma_1^2\right)}. \quad \text{(B.8)}$$

Stage 2:

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

$$p_{s,i} = a_s - q_{s,i} - \gamma_2^s q_{c,j}, \quad \text{(3.3)}$$

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

$$p_{c,j} = a_c - q_{c,j} - \gamma_2^c q_{s,i}, \quad \text{(3.4)}$$

where $\gamma_2^s < \gamma_2^c$. From the inverse demand functions, the demand functions are:

$$q_{s,i} = \frac{\left(a_s - \gamma_2^s a_c\right) - p_{s,i} + \gamma_2^s p_{c,j}}{1-\gamma_2^s\gamma_2^c}, \text{ and } q_{c,j} = \frac{\left(a_c - \gamma_2^c a_s\right) - p_{c,j} + \gamma_2^c p_{s,i}}{1-\gamma_2^s\gamma_2^c}. \text{ Then,}$$

firm i 's profit function is, $\pi_i = (p_{s,i} - c_{s,i})q_{s,i}$

$$= (p_{s,i} - c_{s,i})\frac{\left(a_s - \gamma_2^s a_c\right) - p_{s,i} + \gamma_2^s p_{c,j}}{1-\gamma_2^s\gamma_2^c}$$ and the first order condition is:

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

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

The SOC is $\dfrac{\partial^2 \pi_i}{\partial p_{s,i}{}^2} = \dfrac{2}{\gamma_2^c \gamma_2^s - 1} < 0$; thus, confirming a maximum profit in equilibrium.

Rearranging the FOC, $p_{s,i} = \dfrac{\left(a_s - \gamma_2^s a_c\right) + c_{s,i} + \gamma_2^s p_{c,j}}{2}$, and $p_{c,j} =$ $\dfrac{\left(a_c - \gamma_2^c a_s\right) + c_{c,j} + \gamma_2^c p_{s,i}}{2}$ are obtained. Next, from the reaction functions of firm i and j, the equilibrium prices in stage 2 ($p_{s,i}{}^{2*}$, and $p_{c,j}{}^{2*}$) are:

$$p_{s,i}{}^{2*} = \frac{\left(2a_s - \gamma_2^s a_c - \gamma_2^s \gamma_2^c a_s\right) + 2c_{s,i} + \gamma_2^s c_{c,j}}{\left(4 - \gamma_2^s \gamma_2^c\right)}, \text{ and} \tag{B.9}$$

$$p_{c,j}{}^{2*} = \frac{\left(2a_c - \gamma_2^c a_s - \gamma_2^s \gamma_2^c a_c\right) + 2c_{c,j} + \gamma_2^c c_{s,i}}{\left(4 - \gamma_2^s \gamma_2^c\right)}. \tag{B.10}$$

Then, the equilibrium quantities in stage 2 ($q_{s,i}{}^{2*}$ and $q_{c,j}{}^{2*}$) are:

$$q_{s,i}{}^{2*} = \frac{(2a_s - a_c \gamma_2^s - a_s \gamma_2^s \gamma_2^c) + \gamma_2^s c_{c,j} + (\gamma_2^s \gamma_2^c - 2)c_{s,i}}{4 - 5\gamma_2^s \gamma_2^c + \left(\gamma_2^s\right)^2 \left(\gamma_2^c\right)^2}, \text{ and} \tag{B.11}$$

$$q_{c,j}{}^{2*} = \frac{(2a_c - a_s\gamma_2^c - a_c\gamma_2^s\gamma_2^c) + \gamma_2^c c_{s,i} + (\gamma_2^s\gamma_2^c - 2)c_{c,j}}{4 - 5\gamma_2^s\gamma_2^c + \left(\gamma_2^s\right)^2\left(\gamma_2^c\right)^2}. \qquad (B.12)$$

Also when the equilibrium prices and quantities are plugged back into the profit functions, the equilibrium profits of both firms ($\pi_i{}^{2*}$, and $\pi_j{}^{2*}$) are:

$$\pi_{s,i}{}^{2*} = \frac{\left[\left(a_s\left(\gamma_2^s\gamma_2^c - 2\right) + a_c\gamma_2^s\right) - \gamma_2^s c_{c,j} + \left(2 - \gamma_2^s\gamma_2^c\right)c_{s,i}\right]^2}{\left(\gamma_2^s\gamma_2^c - 4\right)^2\left(1 - \gamma_2^s\gamma_2^c\right)}, \text{ and} \qquad (B.13)$$

$$\pi_{c,j}{}^{2*} = \frac{\left[\left(a_c\left(\gamma_2^s\gamma_2^c - 2\right) + a_s\gamma_2^c\right) - \gamma_2^c c_{s,i} + \left(2 - \gamma_2^s\gamma_2^c\right)c_{c,j}\right]^2}{\left(\gamma_2^s\gamma_2^c - 4\right)^2\left(1 - \gamma_2^s\gamma_2^c\right)}. \qquad (B.14)$$

Stage 3:

In this stage, the follower firm (firm j) also supplies a new sustainable product. Both firms still choose prices as a choice variable, but the game is now a sequential in this stage. The leader will choose its own price first and then the follower will decide to choose their 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,

$$p_{s,i} = a_s - q_{s,i} - \gamma_3 q_{s,j}, \qquad (3.5)$$

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

$$p_{s,j} = a_s - q_{s,j} - \gamma_3 q_{s,i}. \qquad (3.6)$$

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

FOC.
$$\frac{\partial \pi_j}{\partial p_{s,j}} = 0,$$

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

The SOC is $\dfrac{\partial^2 \pi_j}{\partial p_{s,j}{}^2} = \dfrac{2}{(\gamma_3)^2 - 1} < 0$ which implies the maximum equilibrium profit.

From the FOC,

$$\frac{(1-\gamma_3)a_s + \gamma_3 p_{s,i} + c_{s,j}}{2} = p_{s,j}. \qquad \text{(B.15)}$$

Firm j's reaction function is shown in equation (B.15). 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 the reaction function of firm j (equation (B.15)) 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 stage 3 is:

$$p_{s,i}^{3}* = \frac{(2-\gamma_3-\gamma_3^2)a_s+\left(2-\gamma_3^2\right)c_{s,i}+\gamma_3 c_{s,j}}{2(2-\gamma_3^2)}. \tag{B.16}$$

Substituting $p_{s,i}^{3}*$ into the reaction function of firm j, we get the equilibrium price of firm j in stage 3 as:

$$p_{s,j}^{3}* = \frac{(4-2\gamma_3-3\gamma_3^2+\gamma_3^3)a_s+\left(4-\gamma_3^2\right)c_{s,j}+(2-\gamma_3^2)\gamma_3 c_{s,i}}{4(2-\gamma_3^2)}. \tag{B.17}$$

We also check SOC of firm i's profit function; that is $\dfrac{2-(\gamma_3)^2}{(\gamma_3)^2-1} < 0$ which guarantees the maximum equilibrium profit of firm i. Substituting the equilibrium prices into the demand function, so the equilibrium quantities are:

$$q_{s,i}^{3}* = \frac{(2-\gamma_3-\gamma_3^2)a_s-\left(2-\gamma_3^2\right)c_{s,i}+\gamma_3 c_{s,j}}{4(1-\gamma_3^2)}, \text{ and} \tag{B.18}$$

$$q_{s,j}^{3}* = \frac{\left(4-2\gamma_3-3\gamma_3^2+\gamma_3^3\right)a_s-\left(4-3\gamma_3^2\right)c_{s,j}+\left(2-\gamma_3^2\right)\gamma_3 c_{s,i}}{4\left(2-3\gamma_3^2+\gamma_3^4\right)}. \tag{B.19}$$

Finally, the equilibrium profits in stage 3 ($\pi_{s,i}^{3}*$, and $\pi_{s,j}^{3}*$) are:

$$\pi_{s,i}{}^{3}* = \frac{\left((2-\gamma_3-\gamma_3^2)a_s-(2-\gamma_3^2)c_{s,i}+\gamma_3 c_{s,j}\right)^2}{8\left(2-3\gamma_3^2+\gamma_3^4\right)}, \text{ and} \tag{B.20}$$

$$\pi_{s,j}{}^{3}* = \frac{\left(\left(4-2\gamma_3-3\gamma_3^2+\gamma_3^3\right)a_s-\left(4-3\gamma_3^2\right)c_{s,j}+\left(2-\gamma_3^2\right)\gamma_3 c_{s,i}\right)^2}{16\left(\gamma_3^2-2\right)^2\left(1-\gamma_3^2\right)}. \tag{B.21}$$

APPENDIX C: DEMAND UNCERTAINTY: AN EXPANSION OF THE MODEL

The author focuses on an expansion of the model for demand uncertainty. That is whether consumers are willing to pay more for a sustainable product is still questionable for food manufacturers. This issue is important for manufacturers' decision making when considering launching a sustainable product. Many market entry articles are concerned about demand and/or profitability uncertainty (Maggi 1996; Hirokawa and Sasaki 2001; Jeitschko and Creane 2009).

The reasons why the uncertainty on the demand side is explicitly represented in the model are: 1) the author would like to make the model tractable and as simple as possible; therefore, the uncertainty on a supply side is not included in the model, and 2) the firm can control costs, but not consumer demand. Uncertainty is modeled only in stage 2 because for three reasons. First, **stage 1** is the current situation. Firms know the existing demand; hence, there is no uncertainty. Second, in **stage 2** firms never had a sustainable product in the target market, so they cannot predict the consumers' maximum willingness to pay for the new product. Third, since the sustainable product was launched in stage 2, the firms know the consumers' maximum willingness to pay for the new product already. Therefore, there is no uncertainty in **stage 3**.

Many authors applied the real option method to consider uncertainty of launching a product or investing in research and the development of a new product (Smit and Ankum 1993; Grenadier 2000; Botteron, Chesney, and Gibson-Asner 2003; Russo, Cardillo, and Perito 2003; Schwartz and Trigeorgis 2004; Kijima and Shibata 2005). However, the real options is not suitable to our model since the real options 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 for the sustainable product (a_S) is adapted from the demand function in Jeitschko and Creane (2009). An inverse demand function for a sustainable product in stage 2 is adjusted from Jeitschko and Creane (2009) to be $p_{s,i} = [\theta a_S + (1-\theta)a_C] - q_{s,i} - \gamma_2^s q_{c,j}$ where θ represents the leader firm's expectation that consumers would like to pay more for the 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 the sustainable product is defined in Figure 3.16.

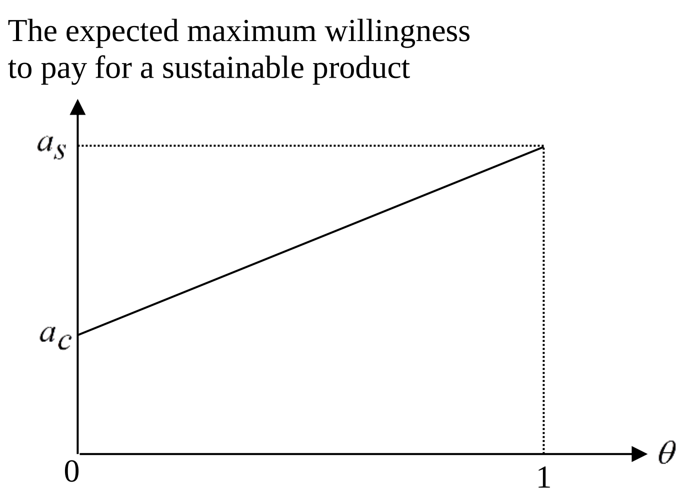

Figure 3.16 The relationship between the expected maximum willingness to pay for the sustainable product (a_S) and the probability that the leader firm expects that consumers are willing to pay more for the sustainable product (θ).

The results when uncertainty is added into the model expand the standard findings and propositions.

Standard Finding 4: When the levels of maximum willingness to pay for the sustainable and conventional product are the same ($a_S = a_C$ or $\theta = 0$), the case with risk and without risk are the same (θ disappears). This is the case because the maximum willingness to pay for the sustainable and conventional product are the same, and uncertainty represented by θ disappears.

Explanation: This assumption represents the worst situation; that is the leader firm expects to get zero premium from the new product. Therefore, there is no uncertainty defined in the model since the firm assumes the lowest maximum willingness to pay for the sustainable product already.

Proposition 6: When $\frac{c_{S,i}}{c_{C,j}} = \frac{a_S}{a_C}$, $\gamma_1 = \gamma_2^c = \gamma_2^s$, and $c_{C,i} = c_{C,j}$, a leader firm i will decide to launch the sustainable product and move to stage 2 if $\theta > \frac{c_{S,i}}{a_S}$.

Explanation: From proposition 6, the leader will get a higher profit when launching the sustainable product if the probability to get the premium from consumers is high enough such that $\theta > \frac{c_{S,i}}{a_S}$. Intuitively, proposition 6 states that the leader will decide to launch a sustainable product when their expectation to get a price premium from the new sustainable product is higher than the ratio of the cost over the maximum willingness to pay for the sustainable product. When θ is equal to 1 or when the leader expects that consumers certainly have a willingness to pay more for the sustainable product, the leader will launch the sustainable product to get a higher profit $\left(1 > \frac{c_{s,i}}{a_s}\right)$ which is consistent with proposition 4a. When θ is equal to 0, or the leader does not expect to get the price premium from the sustainable product, the leader will not launch the sustainable product $\left(0 < \frac{c_{s,i}}{a_s}\right)$.

For the simulation part, it was determined that $\frac{c_{s,i}}{c_{c,j}}$ = 1.66, $c_{c,i}$ = 0.75 (see section 3.5), and $\gamma_1 = \gamma_2^c = \gamma_2^s$ = 0.7. Figure 3.17 shows the simulation results, which are consistent with proposition 6. That is $\pi_{s,i}{}^{2*} - \pi_{c,i}{}^{1*}$ is a positive value when $\theta > \frac{c_{s,i}}{a_s}$, or the leader will get a higher profit when launching the sustainable product if $\theta > \frac{c_{s,i}}{a_s}$.

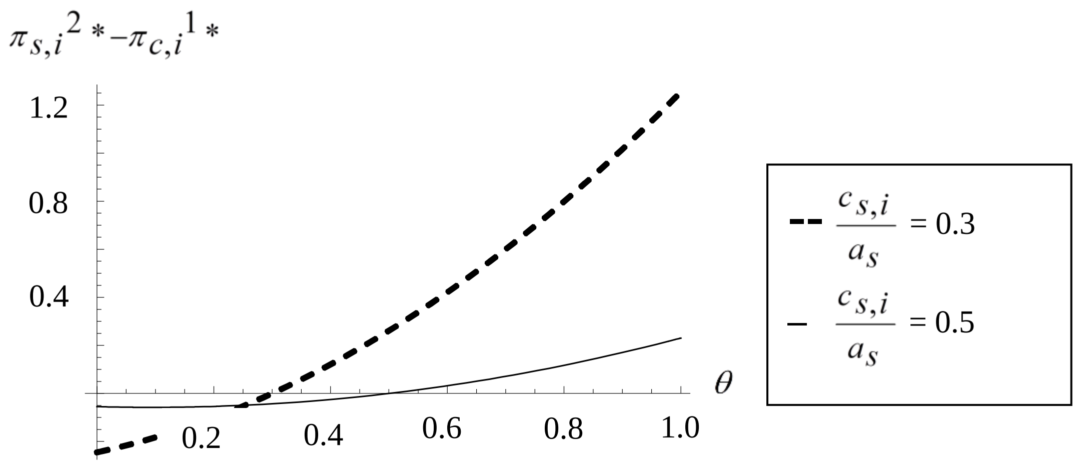

Figure 3.17 Leader profit simulation between stages 1 and 2 ($\pi_{s,i}{}^{2*} - \pi_{c,i}{}^{1*}$) varying the probability of leader's expectation that consumers are willing to pay more for the sustainable product (θ) for two levels of the cost over the maximum willingness to pay $\left(\frac{c_{s,i}}{a_s}\right)$, 0.3 and 0.5.

Proposition 7: When $\frac{c_{s,i}}{c_{c,j}} = \frac{a_s}{a_c}$, and the degree of substitution of the conventional and sustainable product are the same in stage 2 ($\gamma_2^c = \gamma_2^s$), the leader will get a higher profit than the follower if $\theta > \frac{c_{s,i}}{a_s}$.

Explanation: Proposition 7 is similar to proposition 6, except it compares the leader's profit and the follower's profit in stage 2 instead of comparing the leader's profits in stages 1 and 2. The leader will get a higher profit than the follower when $\theta > \frac{c_{s,i}}{a_s}$ or when the expectation of a price premium from the new sustainable product is high enough or higher than the cost over the maximum willingness to pay for the sustainable product. When the leader expects that consumers have a willingness to pay more for the sustainable product (θ = 1), the leader has a higher profit than the follower $\left(1 > \frac{c_{s,i}}{a_s}\right)$, which is consistent with proposition 5a. When θ is equal to 0, the leader gets less profit than the follower $\left(0 < \frac{c_{s,i}}{a_s}\right)$, which is consistent with standard finding 4.

Assuming that $\frac{c_{s,i}}{c_{c,j}}$ = 1.66, $c_{c,i}$ = 0.75, and $\gamma_1 = \gamma_2^c = \gamma_2^s$ = 0.7, figure 3.18 shows the simulation results, which are consistent with proposition 7. That is $\pi_{s,i}{}^{2*} - \pi_{c,j}{}^{2*}$ is a positive value when $\theta > \frac{c_{s,i}}{a_s}$ meaning that the leader will get a higher profit when launching a sustainable product if $\theta > \frac{c_{s,i}}{a_s}$.

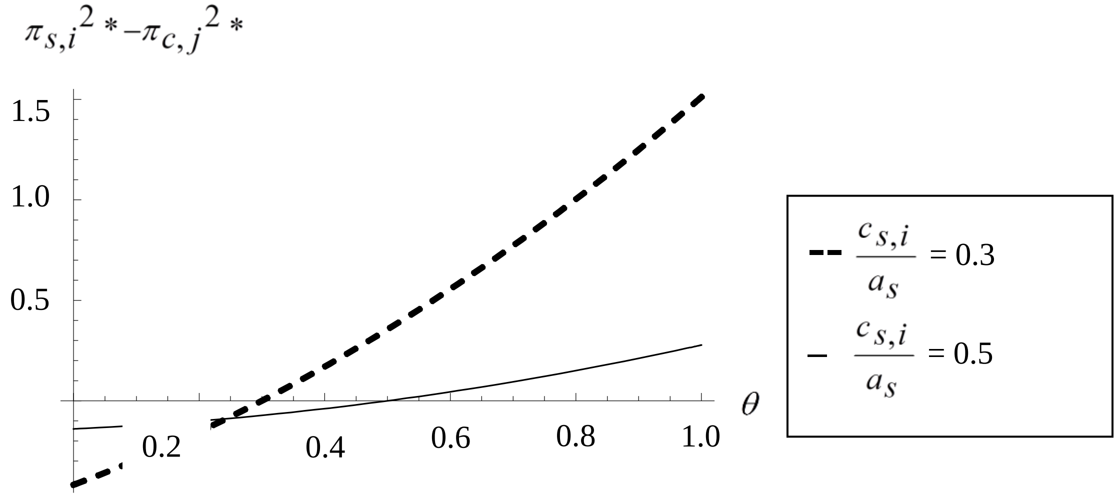

Figure 3.18 Profit simulation between two firms in stage 2 ($\pi_{s,i}^{2*} - \pi_{c,j}^{2*}$) varying the probability that the leader expects that consumers are willing to pay more for the sustainable product (θ) for two levels of the cost over the maximum willingness to pay $\left(\frac{c_{s,i}}{a_s}\right)$, 0.3 and 0.5.

Figure 3.19 is an expansion of figure 3.15. It shows all standard findings, propositions and their restrictions when including risk variable (θ) in the model.

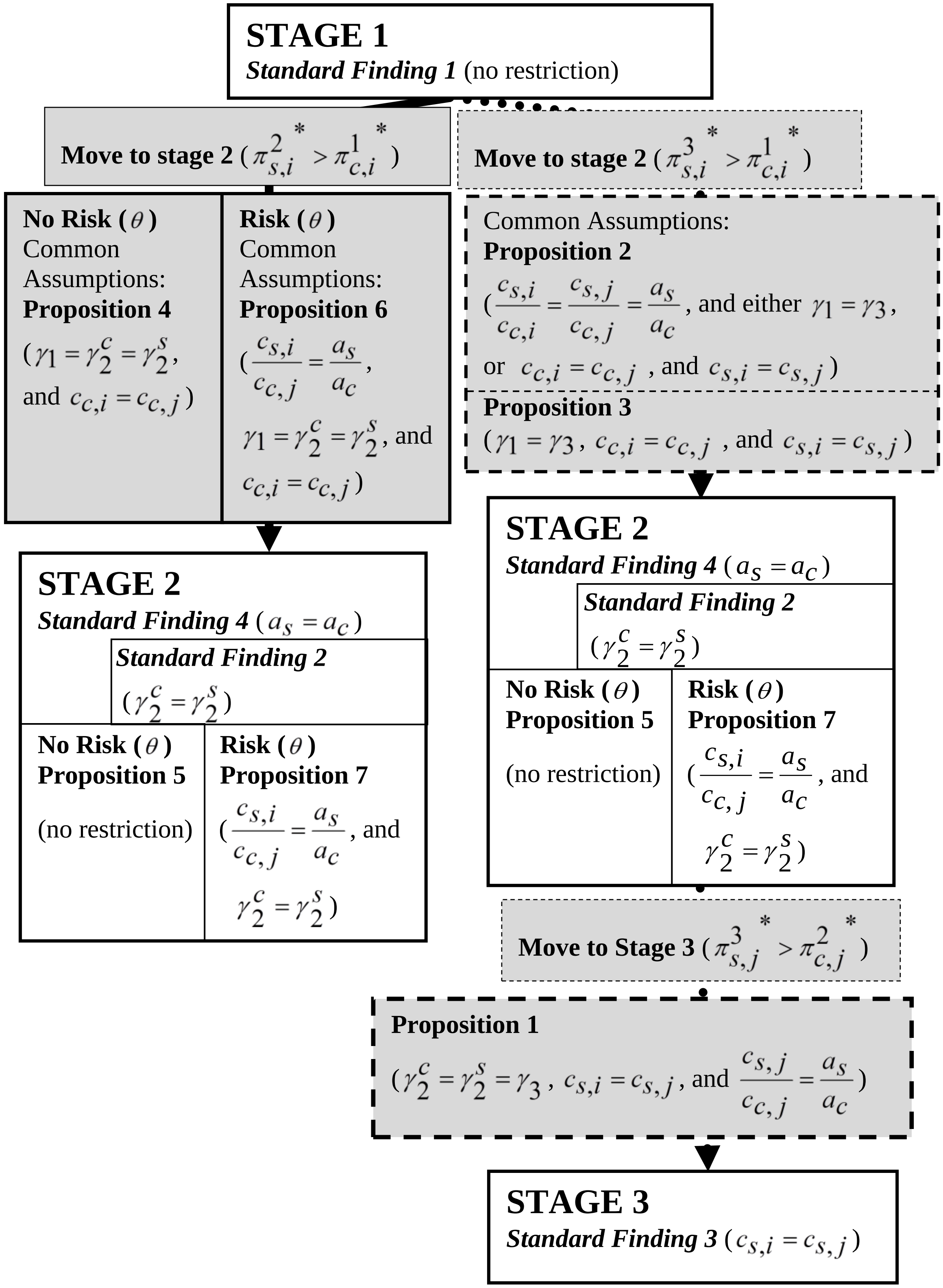

Figure 3.19 Summary of decision making arranged by propositions, standard findings and their restrictions when uncertainty is introduced.

APPENDIX D: THE PROOF AND DERIVATION FOR PROPOSIONS AND STANDARD FINDINGS

Proposition 1 Proof

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

$$\times\left(-\frac{\left(\left(\gamma_2^s\right)^3 - 3\left(\gamma_2^s\right)^2 - 2\gamma_2^s + 4\right)^2}{\left(\left(\gamma_2^s\right)^2 - 2\right)^2} + \frac{16\left(\left(\gamma_2^s\right)^2\frac{1}{z} + \gamma_2^s - 2\frac{1}{z}\right)^2}{\left(\left(\gamma_2^s\right)^2 - 4\right)^2}\right).$$

$\frac{\left(a_c - c_{c,j}\right)^2}{16\left(\left(\gamma_2^s\right)^2 - 1\right)\left(\frac{1}{z}\right)^2}$ is a negative value since $0 < \gamma_2^c < 1$.

$-\frac{\left(\left(\gamma_2^s\right)^3 - 3\left(\gamma_2^s\right)^2 - 2\gamma_2^s + 4\right)^2}{\left(\left(\gamma_2^s\right)^2 - 2\right)^2} + \frac{16\left(\left(\gamma_2^s\right)^2\frac{1}{z} + \gamma_2^s - 2\frac{1}{z}\right)^2}{\left(\left(\gamma_2^s\right)^2 - 4\right)^2}$ will be a negative value

if $\frac{\left(\left(\gamma_2^s\right)^3 - 3\left(\gamma_2^s\right)^2 - 2\gamma_2^s + 4\right)^2}{\left(\left(\gamma_2^s\right)^2 - 2\right)^2}$ is greater than $\frac{16\left(\left(\gamma_2^s\right)^2\frac{1}{z} + \gamma_2^s - 2\frac{1}{z}\right)^2}{\left(\left(\gamma_2^s\right)^2 - 4\right)^2}$. The conditions to make $\dfrac{((\gamma_2^s)^3 - 3(\gamma_2^s)^2 - 2\gamma_2^s + 4)^2}{((\gamma_2^s)^2 - 2)^2}$ greater than

$\dfrac{16\left((\gamma_2^s)^2 \frac{1}{z} + \gamma_2^s - 2\frac{1}{z}\right)^2}{((\gamma_2^s)^2 - 4)^2}$ are shown in proposition 1.

Proposition 2 Proof

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

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

$\times\left(\gamma_3^4 + 8\gamma_3^2\left(\left(\frac{1}{z}\right)^2 - 1\right) - 16\left(\left(\frac{1}{z}\right)^2 - 1\right)\right)$. Since both terms are positive values,

$\pi_{s,i}^{*\,3} - \pi_{c,i}^{*\,1}$ is always greater than zero.

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

$$\pi_{s,i}^{3}* - \pi_{c,i}^{1}* = \frac{1}{8}\left(a_s - c_{s,j}\right)^2 \left(\frac{(\gamma_3 - 1)(\gamma_3 + 2)^2}{\gamma_3^3 + \gamma_3^2 - 2\gamma_3 - 2} + \frac{8(\gamma_1 - 1)\left(\frac{1}{z}\right)^2}{(\gamma_1 - 2)^2(\gamma_1 + 1)} \right)$$

. The first term is a positive value and the second term is a positive value since

$\left| \frac{(\gamma_3 - 1)(\gamma_3 + 2)^2}{\gamma_3^3 + \gamma_3^2 - 2\gamma_3 - 2} \right|$ is greater than $\left| \frac{8(\gamma_1 - 1)\left(\frac{1}{z}\right)^2}{(\gamma_1 - 2)^2(\gamma_1 + 1)} \right|$. Therefore, $\pi_{s,i}^{*\,3} - \pi_{c,i}^{*\,1}$ is always greater than zero.

Proposition 3 Proof

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

. The first term is a negative value. $\frac{(a_s - c_{s,j})^2(\gamma_3 + 2)^2}{\gamma_3^3 + \gamma_3^2 - 2\gamma_3 - 2}$ is a negative value while

$\frac{8(c_{s,j}\left(\frac{1}{y}\right) - a_s\left(\frac{1}{z}\right))^2}{(\gamma_3 - 2)^2(\gamma_3 + 1)}$ is a positive value. The second term will be a negative value when $\left|\dfrac{(a_s - c_{s,j})^2(\gamma_3+2)^2}{\gamma_3^3+\gamma_3^2-2\gamma_3-2}\right|$ is greater than $\left|\dfrac{8(c_{s,j}\left(\frac{1}{y}\right)-a_s\left(\frac{1}{z}\right))^2}{(\gamma_3-2)^2(\gamma_3+1)}\right|$ or when the

conditions shown in proposition 3 are satisfied.

Proposition 4 Proof

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

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

. The first term ($\dfrac{1}{\left(\left(\gamma_2^c\right)^2-4\right)^2\left(\left(\gamma_2^c\right)^2-1\right)}$) is a negative value since $0<\gamma_2^c<1$. The

second term is a negative value when $\left(\left(\gamma_2^c\right)^2+\gamma_2^c-2\right)^2\left(c_{s,i}\frac{1}{y}-a_s\frac{1}{z}\right)^2$ is less than

$\left(c_{s,i}\left(\left(\gamma_2^c\right)^2+\gamma_2^c\frac{1}{y}-2\right)-a_s\left(\left(\gamma_2^c\right)^2+\gamma_2^c\frac{1}{z}-2\right)\right)^2$. The conditions that make the

second term a negative value are shown in proposition 4.

Standard Finding 1 Proof

The difference of profits in stage 1 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 denominator is a negative value since $0 < \gamma_1 < 1$ and the first term of the numerator 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, and vice versa. Moreover, γ_1 has no effect on the sign of $\pi_{c,i}^{1}* - \pi_{c,j}^{1}*$, but does have an effect on the amount of difference in profits.

Standard Finding 2 Proof

When $\gamma_2^c = \gamma_2^s$, and $a_s = a_c$, $\pi_{s,i}^{2}* - \pi_{c,j}^{2}*$ is

$$\frac{c_{s,i}\left(c_{s,i}\left(\left(\frac{1}{y}\right)^2 - 1\right) - 2a_s\left(\left(\frac{1}{y}\right) - 1\right)\right)}{\left(\gamma_2^c\right)^2 - 4}$$ which equals

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

$0 < \gamma_2^c < 1$. The numerator is a positive value since $0 < \left(\frac{1}{y}\right) < 1$ and $c_{s,i} < a_s$. Thus,

$\pi_{s,i}{}^{2*}$ - $\pi_{c,j}{}^{2*}$ is less than zero.

Proposition 5 Proof

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

$$+$$

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

The first term is a positive value while the second term is a negative value since $0 < \gamma_2^c < 1$ and $1 < x$. $\pi_{s,i}{}^{2*} - \pi_{c,j}{}^{2*}$ will be greater than zero when the absolute value of the first term is greater than the absolute value of the second term; that is when the conditions in proposition 5 are satisfied.

Standard Finding 3 Proof

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

Standard Finding 4 Proof

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

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

Proposition 6 Proof

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

$$\left(c_{c,j}\left((\gamma_1)^2 + \gamma_1\left(\frac{1}{z}\right) - 2\right) + a_c\left(\frac{1}{z}\left((\gamma_1)^2(\theta-1) - \gamma_1 - 2(\theta-1)\right) - \theta\left((\gamma_1)^2 - 2\right)\right)\right)^2 z^2].$$

The first term is a negative value while the second term can be a positive or negative value. Thus $\pi_{s,i}{}^{2}*$ - $\pi_{c,i}{}^{1}*$ will be a positive value when the second term is a negative value or when the condition in proposition 6 is satisfied.

Proposition 7 Proof

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

denominator is a negative value since $0<\gamma_2^c<1$. The numerator is a negative value

when $\left(c_{s,i}\left(\frac{1}{z}+1\right)+a_s\left(\frac{1}{z}(\theta-2)-\theta\right)\right)(c_{s,i}-a_s\theta)$ is a negative value since $1<z$. The

condition that makes $\left(c_{s,i}\left(\frac{1}{z}+1\right)+a_s\left(\frac{1}{z}(\theta-2)-\theta\right)\right)(c_{s,i}-a_s\theta)$ a negative value is

shown in proposition 7.

APPENDIX E: SIMULATION STEPS AND EXAMPLE

The Steps for Simulation

The information from the egg industry is used for simulation. The steps for simulation are described as follows:

Step 1: Find the difference in profits.

Step 2: Substitute the value of the parameters by using the information from the egg industry.

Step 3: Substitute the restriction(s) of each proposition/standard finding.

Step 4: Arbitrarily determine the value of some unobserved parameters, such as the degrees of substitution, and the levels of maximum willingness to pay for the sustainable and conventional product. These depend on the restriction(s) of each proposition/standard finding and in which parameter is of interest.

Step 5: Plot a graph where the y-axis represents the difference in profit and the x-axis is an unobserved variable which is related to the proposition/standard finding.

Simulation Example

An example used to demonstrate the steps for simulation is how to determine the shape in figure 3.3 which explains proposition 1. Proposition 1 shows under which conditions the follower decides to launch a sustainable product. The steps for simulation are as follows:

Step 1:

Compare the follower's profits in stages 2 and 3. That is, the follower will launch a sustainable product when its profit in stage 3 is higher than its profit in stage 2 ($\pi_{s,j}{}^{3*} > \pi_{c,j}{}^{2*}$) or when the difference in profits for figure 3.3 ($\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$) is a positive value. From Mathematica $\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ is

$$\frac{\left(2(a_c - c_{c,j}) - \gamma_2^c(a_s - c_{s,i}) - \gamma_2^c\gamma_2^s(a_c - c_{c,j})\right)^2}{\left(\gamma_2^c\gamma_2^s - 4\right)^2\left(\gamma_2^c\gamma_2^s - 1\right)}$$
$$-\frac{\left(\gamma_3 c_{s,i}\left(2-(\gamma_3)^2\right) - c_{s,j}\left(4-3(\gamma_3)^2\right) + a_s\left(4-\gamma_3\left(2+3\gamma_3-(\gamma_3)^2\right)\right)\right)^2}{16\left((\gamma_3)^2-2\right)^2\left((\gamma_3)^2-1\right)}.$$

Step 2:

The cost for conventional eggs ($c_{c,j}$) from the egg industry is \$0.75 per dozen, and the relative cost $\left(\frac{c_{s,i}}{c_{c,j}}\right)$ of the sustainable product for the worst case scenario is 1.66.

Substituting these values into $\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ equation, $\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ is equal to

$$\frac{\left(1.49 + \gamma_2^c\left(a_s - 0.75\gamma_2^s - 1.24\right) + a_c\left(\gamma_2^c\gamma_2^s - 2\right)\right)^2}{\left(\gamma_2^c\gamma_2^s - 4\right)^2\left(\gamma_2^c\gamma_2^s - 1\right)} -$$

$$\frac{0.06\left(2.47\gamma_3 - 1.24(\gamma_3)^2 + a_s(\gamma_3 - 3.24)(\gamma_3 - 1)(\gamma_3 + 1.24) + c_{s,j}\left(3(\gamma_3)^2 - 4\right)\right)^2}{\left((\gamma_3)^2 - 2\right)^2\left((\gamma_3)^2 - 1\right)}.$$

Step 3:

Substitute the restrictions of proposition 1 into $\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ from step 2. The

restrictions are $\gamma_2^c = \gamma_2^s = \gamma_3$, $c_{s,i} = c_{s,j}$, and $\dfrac{c_{s,j}}{c_{c,j}} = \dfrac{a_s}{a_c}$. Then, $\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ is

$$\frac{1}{16\left(\left(\gamma_2^s\right)^2 - 1\right)} \frac{(-1)(-a_s + 1.24)^2\left(\gamma_2^s - 3.24\right)^2\left(\gamma_2^s - 1\right)^2\left(\gamma_2^s + 1.24\right)^2}{\left(\left(\gamma_2^s\right)^2 - 2\right)^2}$$

$$\frac{16\left(-0.75\left(\gamma_2^s - 0.81\right)\left(\gamma_2^s + 2.47\right) + a_s\left(-1.20 + \gamma_2^s + 0.60\left(\gamma_2^s\right)^2\right)\right)^2}{\left(\left(\gamma_2^s\right)^2 - 4\right)^2}.$$

Step 4:

We assume that a_s = 5; then substitute this value into $\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ in step 3. Thus,

$\pi_{s,j}{}^{3*} - \pi_{c,j}{}^{2*}$ equals $\dfrac{-1}{\left(\left(\gamma_2^c\right)^2 - 1\right)\left(8 - 6\left(\gamma_2^c\right)^2 + \left(\gamma_2^c\right)^4\right)^2}$

$$[0.89\left(\gamma_2^s - 6.30\right)\left(\gamma_2^s - 1.59\right)\left(\gamma_2^s - 1.15\right)\left(\gamma_2^s - 0.93\right)\left(\gamma_2^s + 0.96\right)$$
$$\left(\gamma_2^s + 1.31\right)\left(\gamma_2^s + 1.83\right)\left(\gamma_2^s + 2.11\right)\left(3.13 - 2.24\gamma_2^s + \left(\gamma_2^s\right)^2\right)].$$

Step 5:

From step 4, $\pi_{s,j}^{3*} - \pi_{c,j}^{2*}$ is a function of only γ_2^s. Therefore, we can draw the graph of $\pi_{s,j}^{3*} - \pi_{c,j}^{2*}$ by determining $\pi_{s,j}^{3*} - \pi_{c,j}^{2*}$ as the y-axis and γ_2^s as the x-axis as shown in figure 3.20.

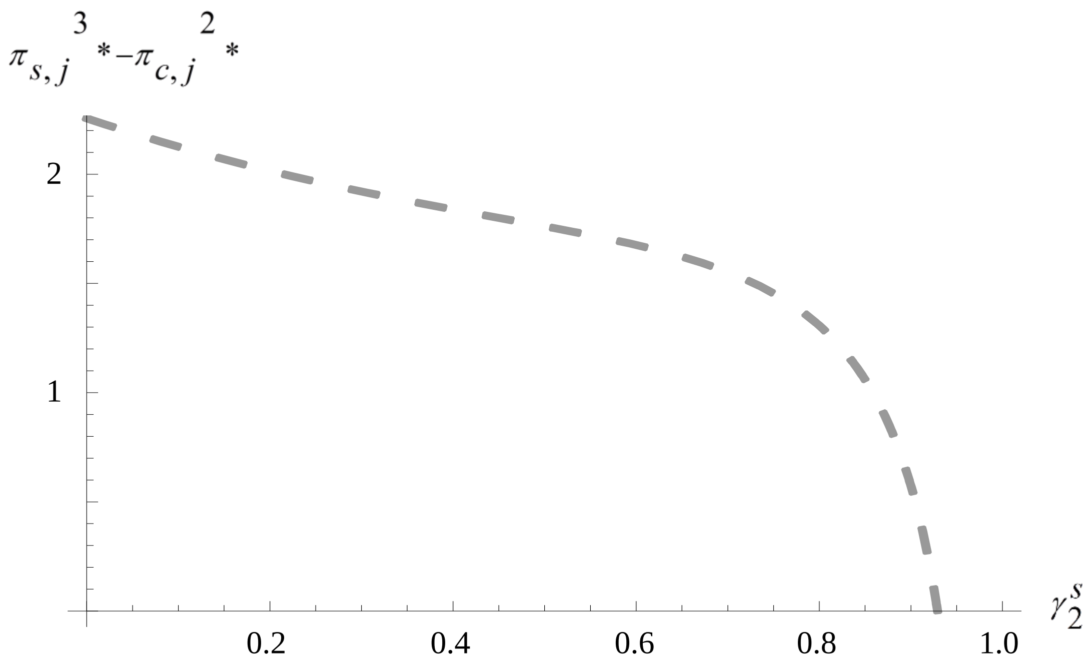

Figure 3.20: Profit simulation between stages 2 and 3 for the follower varying the degrees of substitution ($\gamma_2^c = \gamma_2^s = \gamma_3$) when the level of relative costs of a sustainable product $\left(\frac{c_{s,j}}{c_{c,j}}\right)$ equals 1.66 (the worst case scenario).

When these steps are repeated for the case that $\frac{c_{s,j}}{c_{c,j}}$ equals 1.2, the graph can be illustrated as in figure 3.3.

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CHAPTER 4: CONCLUSION

This dissertation studies sustainability within the food system. It estimates the: 1) value of sustainable attributes, 2) the food manufacturers' decision making on whether to launch a sustainable product, and 3) then simulates results from the U.S. egg industry. The first study informs food firms about price premiums of sustainable attributes as one of the deciding factors on launching a sustainable product. The second paper constructs a systematic product-launching decision model and suggests under which conditions firms decide to launch a sustainable product and/or encourage a firm to be a leader that markets a sustainable product first.

The first paper found that the welfare-managed attributes, free-range and/or cage-free attribute were positively and significantly related to the price of eggs. The welfare-managed attribute has a price premium equal to 3.57 cents over a standard conventional egg. The attribute that has the highest premium was the organic attribute which increases the price per egg by 16.50 cents. Surprisingly, the premium of the stack attributes, organic and welfare-managed attributes together, equals only 11.26 cents per egg which was less than the premium of the organic attribute. This implies that consumers may be confused about the difference between organic and welfare-managed attributes and are not willing to pay for both labeled attributes simultaneously. Consequently, in the short run, egg manufacturers could maximize profit by offering and labeling either organic or welfare-managed eggs until consumers perceive the difference between these two attributes.

The second paper constructed a model for food manufacturers' decision making to launch a sustainable product by employing game theory. There are two main conditions that influence a *leader* food firm to launch a sustainable product. The first condition is that the relative cost of a sustainable product over a conventional product is lower than or equal to the relative maximum willingness to pay for a sustainable product over a conventional product. This implies that an additional cost to produce a sustainable product has to be covered by an additional maximum willingness to pay for a sustainable product to induce the leader food firms to launch a sustainable product. The second condition is that if the first condition is not satisfied, it is profitable for the leader firm to launch a sustainable product only when an absolute value of the maximum willingness to pay for a sustainable product is sufficiently higher than the absolute cost of the sustainable product.

The conditions to support a *follower* food firm to launch a sustainable "me-too" product are different from a leader's conditions. Firstly, the follower food firm decides to launch a sustainable product when consumers realize that there is a difference between conventional and sustainable products. In addition, consumers have to prefer and be willing to pay more for the sustainable product. Secondly, even if the first condition does not hold, the follower food firm will still decide to launch a sustainable product when the costs of a sustainable and conventional product are sufficiently close.

The second study also determines under which conditions food firms are encouraged to be a leader in the sustainable product market. A firm decides to be a leader when it has a cost advantage to produce a sustainable product, and a cost disadvantage to produce a conventional product. Moreover, the firm decides to be a leader when the relative cost of a sustainable product over a conventional product is less than or equal to the relative maximum willingness to pay for a sustainable product over a conventional product which is the same condition that encourages the leader firm to launch a sustainable product. Simulations from the egg industry show that both a leader and a follower attain higher profits when they decide to launch a sustainable egg product. These results are supported by observation and data from the U.S. Egg Industry. That is, from the Mintel's Consumer Survey Data, the percentage of consumers who buy free-range or cage-free eggs increased from 9% in 2008 to be 14% in 2011 (Mintel, 2008 and Mintel, 2011).

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