STRATEGIES FOR GREEN PRODUCT DEVELOPMENT

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This dissertation is lovingly dedicated to my mother, *Fatma Yenipazarli*.

Her infinite love, unconditional support and continuous encouragement have sustained me throughout my life and helped me fight my recent health problem.

I miss you every single day we are not together.

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STRATEGIES FOR GREEN PRODUCT DEVELOPMENT

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Back in the 1960s, a small group of consumers preferred "green" products and this was viewed in general as a fringe fad. In the last 5 decades due to several reasons, we have witnessed consumers shift from being highly skeptical about the performance of green products to the commoditization of green in many categories. Few would now question the fact that "green" is decidedly becoming the norm. Is every consumer making every purchase decision based on "green" product attributes? No - far from it. However, we observe that: there are finely defined segments of green consumers; consumer purchasing is guided by values such as how products are sourced, manufactured, packaged and disposed off; a growing number of people are willing to pay premium for "green" products; "green" inspires innovative products that can result in better consumer value, enhanced brands and a stronger company; and "green" is shaping the agendas of governments and non-governmental organizations.

This research examines green product strategies implemented in response to the changing rules of consumer markets, and in order to reduce a firm's environmental footprint while simultaneously increasing its profitability and market share. Reflecting the swiftly changing attitudes and purchasing behaviors of today's consumers, these strategies cover highlighting inherent green attributes in existing products, greening current product offerings, inventing new sustainable products, and/or acquiring brands with "green" ingrained in their corporate philosophy. Once perceived as a niche

opportunity but more often as a burden that represents added cost and overhead, many companies are quickly growing their businesses nowadays through implementing these strategies that enable them extend their appeal from a once very fringe audience to now mainstream consumers. However, it is important to realize that “going green” has not fulfilled its promise for some other firms and this might be attributed to an incomplete understanding of the strategy choices. This research analyzes and proposes underlying drivers of each strategy to help companies transform challenges in the green marketplace into opportunities and re-imagine their products. The analytical and extensive numerical analysis carried out in this research underline that any company striving to succeed in the green marketplace need to comply not just with the laws of government, but also with the laws of the marketplace and the nature.

CHAPTER 1
INTRODUCTION

1.1 Green Products and Green Shopping: from Sub-Culture to Common Culture

Not too long ago, green shoppers in the marketplace were only a minority and they were all dismissed as hemp-wearing, tree-hugging and trash-sorting hippies with inadequate buying power to draw attention to green products. At that time, the environmental debate was viewed just as an over-reaction of misguided environmentalists. They were treated with scorn and ridicule, and even bore the brunt of many comedians' late-night shows. Green shopping was viewed as part of a fringe lifestyle and green products could not find their ways into the shopping lists of most consumers. Hence, it is not surprising that green products did not even appear in firms' To-Do lists because environment was not the focus of public attention and debate, and most firms tended to follow the old phrase "if it ain't broke, don't fix it." The widespread thinking was "This is a bad thing for our bottom line." Products claiming to be "green" were mostly from tiny mom-and-pop firms and they had all gathered dust on the bottom shelves of the stores, if not forgotten at all in back rooms or basements. More importantly, those products used to carry a negative baggage: they did not perform as well as their conventional alternatives and were not a good value. In addition, the drop-off sites for recycling were too few, and you had to haul your used newspapers, milk cartons or plastic bottles to locations on the far side of the town. Green products almost never made the headlines of newspapers, were not a reliable story element on the nation's news channels, and publications in the print media about them were limited to only a certain number of idealist magazines like Mother Jones® and Utne Reader®. After all, "green" was just a color for the majority, and the words *green* and *repulsive* had become more or less synonymous for the mainstream shoppers.

That is all water under the bridge. Now everything has changed and green shopping has reached a tipping point. Today, there are substantial numbers of consumers who are espousing environmental values and changing their shopping lists. Consumers with varying degrees of environmental concern represent 87% of the adult population in the U.S., and have a willingness to buy green products[1] . The waves of consumer desire for green products have finally earned mainstream understanding to drive action. Thanks in part to advances in technology, recent natural events and disasters, governments and even celebrities, a growing selection of today's green products are alluring, highly accessible, and designed to deliver convenience, lower costs and perform better than their "brown" counterparts. More notably they are on the rise nowadays. Today, you hear the quite hum of a Toyota Prius® curling around the corner; taste the organic coffee in your Starbucks mug; see hemp shirts, sweaters and three-button suits in an Emporio Armani collection; find hundreds of green-certified products ranging from light bulbs and baby food to flat-panel TVs in any Wal-Mart store; see the United States Department of Agriculture (USDA) Organic certified products lined up on the shelves of your local grocer; photograph the mannequin of Prince Charles in the Madame Tussauds museum that is made up of organic beeswax; watch a green wedding with soy candles and groom's hemp suit on the NBC's soap opera "Days of Our Lives®"; read green stories in the Washington Post® each day and see green products featured on the covers of BusinessWeek® and the New York Times Style Magazine®. Green shopping has remarkably been going from a sub-culture to a common culture, and it seems to have permeated every aspect of our lives.

Interest in green shopping is not just here to stay; it is also growing rapidly. The Natural Marketing Institute predicted the green marketplace to reach $420 billion by 2010, and $845 billion by 2015. Even the ongoing economic woes have not deterred green sentiments in purchasing behavior, nor consumers' expectations that companies will develop high-quality green products. Information Resources, Inc. found that

[1] http://www.ats.agr.gc.ca/amr/4531-eng.htm, accessed December 5, 2010.

consumers are actually maintaining or increasing spending on green products in spite of the recent economic downturn[2] . Green products are increasingly becoming widespread on the shelves, and an overwhelming majority of shoppers are now putting green products into their shopping carts. Thus, green shopping is not how it once was: It has evolved from a sub-culture, is now getting traction in the marketplace and being expected to grow with time. When we step back for a moment to look back and analyze its evolution, we better understand that green shopping and the proliferation of green products have recently picked up pace as a result of various factors ranging from the shift in consumer mindset to governments and social media, yet it all starts with an intriguing question: What is a green product?

1.2 What Exactly Makes a Product "Green"?

Green. It is the new buzzword in today's marketplace that is widely used to designate at the broadest level environmentally benign products. Ironically, no consumer product is truly green; each product generates an environmental footprint. Products and processes used to manufacture them consume fuel/energy, utilize non-renewable materials/resources and generate toxic/harmful emissions, and product designers continually face trade-offs between such environmental impacts. A product can be entirely made of renewable materials and decay completely at the end of its life. However, a substitute product may use fewer resources during its production that results in the release of fewer hazardous emissions. Consider, for example, the package of a modern snack chip bag. A lightweight package, made of a combination of extremely thin layers of several different materials, has certain waste prevention attributes: It has a longer shelf-life (leading to less food waste) and lighter than an equivalent single-material package, but the use of certain materials inhibits recycling. Similarly, a

[2] http://symphonyiri.com/?TabId=97&ItemID=749&View=Details, accessed December 6, 2010.

car bumper can be made recyclable using steel instead of glass-reinforced plastic, yet glass-reinforced plastic is lighter and results in less fuel use over the lifetime of the car. Then, which one makes it more green, the ability to recycle or the lighter weight?

Such trade-offs are unavoidable, and rarely is a product unambiguously preferable with respect to its impact on the environment in every dimension (e.g., recyclability, energy use, emissions). That is why generally a green product cannot be defined in any absolute sense, and there is no widespread consensus or agreement on what makes a product green. Some of the industry and organizational definitions are as follows:

- Greenpeace rates the greenness of brand name electronics products based on the use of hazardous chemicals, energy efficiency, recyclability and upgradeability;[3]
- Global Green assesses greenness based on factors such as energy savings, water conservation, contribution to a safe and healthy environment, protection of natural resources, and reduction of a negative impact on community;[4]
- Nokia focuses on material usage, infrastructure and embedded energy, sustainable sourcing, recycling and refurbishment, energy consumption, and product lifetime;[5] and
- LG defines their green products as "minimizing the environmental impact on the whole value chain and enriching your life."[6]

Even though no product has a zero impact on the environment, the definitions above show that a green product is typically characterized by multiple product attributes (e.g., content of recycled materials, energy usage during its operational life, and sustainable

[3] http://www.greenpeace.org/international/en/news/features/green-electronics-050308, accessed July 22, 2010.

[4] http://www.globalgreen.org/greenurbanism/whatmakesgreen, accessed July 22, 2010.

[5] http://www.nokia.com/corporate-responsibility/environment/case-studies/green-products, accessed July 22, 2010.

[6] http://www.lg.com/global/sustainability/environment/green-products/eco-design.jsp, accessed July 22, 2010.

sourcing practices). The problem here is how green boundaries would be delineated: What dimensions of green should be taken into account? Materials? Energy? Toxicity? Supply chain practices? From here onwards, we use the term “green product” to describe products that strive to protect or enhance the natural environment by either (1) using recycled materials, (2) reducing or eliminating harmful chemicals and solvents, (3) conserving energy or water, (4) creating less emissions, pollution and waste, (5) using organic or pesticide-free farming methods, and/or (6) increasing the productivity of natural resources.

1.3 Motivation Behind the Development of Green Products

There is a wider selection of green choices available on supermarket shelves primarily due to the growing global concern about the environment. Nearly every product category now offers a dizzying variety of green options. According to the latest “Green Living” report from Mintel International Group, a Chicago-based market research firm, the number and diversity of green products skyrocketed between 2002 and 2010: In 2002, 20 green products were introduced in only 8 product categories (including food, personal care and cleaning categories) which grew to 34 categories (as diverse as air care, home cleaning equipment and color cosmetics) within just 4 years. In 2008, the number of green products grew more than 300% compared to previous year, and since then it continues to grow by around 40% each year. In addition, the year 2010 saw a surge of new green products in the household cleaning, laundry and air freshener categories, with more than 400 new products in the U.S. market.

The pool of green products continues to grow at a rapid rate because green products’ share of what goes into each consumer’s cart increases. Consumers’ interest in green shopping turns out to be not a passing trend or fickle, and apparently it has been gaining forefront attention of companies. Today, mainstream consumer-products giants are diligently taking steps toward architecting green offerings - building green products from scratch or redesigning their existing products - or even acquiring leading sustainable brands. Toyota's fuel-efficient Prius®, P&G's Duracell® rechargeable batteries, energy-saving Tide Coldwater® laundry detergents and PUR® water filtration products, Philip's Marathon® bulbs, Whirlpool's Duet® front-loading washers and dryers, natural personal-care products of Tom's of Maine and Ben & Jerry's ice cream are just some of the notable examples of this trend. It is clear that the entire green market is ripe for branding efforts today. Once offered under brand names no one had never heard of and gathered dust on the shelves, green products are no longer fringe products, but rather they are attractive, highly demanded and easily accessible on almost every store's specially treated shelves. This brings into focus two important questions: What is behind the growing interest in green choices? What are the key drivers related to the proliferation of green products?

1.3.1 The Shift in Green Behavior

Green behavior is moving from "hype" to "habit" - environmentally considerate behavior is becoming a part of everyday life. Green shopping may not appeal to everyone yet, but there are already substantial numbers of potential consumers that are receptive to a green appeal. People do appear to be actively changing their lifestyles to help the environment, and even little changes can help quite a bit. Recently, almost all of U.S. population have engaged in various green practices - from taking their reusable bags to the grocery stores to turning off the tap when brushing their teeth or composting kitchen scraps/garden waste - in their daily lives. In 2007, 95% of U.S. citizens conserved energy by turning off the lights, 90% turned off electronics when not in use, 86% controlled thermostat to conserve energy and 67% recycled paper (e.g., newspaper)[7] . There is also quite a bit of action in purchasing behaviors. The majority of U.S. citizens would prefer to choose a green product over one that is less friendly to

[7] Natural Marketing Institute, "Understanding the LOHAS Market Report," March 2008.

the environment in categories such as automobiles (66%), clothes detergents (62%) and computer printer paper (51%). Notably, about three in ten consumers report that they regularly boycott a brand or company that they perceive to be socially irresponsible, up 10% since 2006. So, avoidance is not an option anymore, and most consumers are regularly factoring green sentiments into their habits and shopping behaviors.

This has led to more well-defined segments of green consumers in the marketplace. Not everyone responds to green products in the same way - consumers are not indifferent to the value offered by green products. In order to have a good portrait of the environmental attitudes of their customers and fine-tune their products, packaging, marketing messages and all the other complexities of bringing products to market, companies have recently put forth their efforts to segment the market into different shades of green. Accordingly, the 2002 public opinion survey from GfK Roper Public Affairs & Media introduced a five-part segmentation of the environmental marketplace based on consumers' environmental attitudes and propensity to purchase green products. In Roper's parlance, the five segments of the U.S. population are:

- *True Blue Greens* (10%): are the most environmentally active segment of society, true environmental activists and leaders, and most likely to walk the green talk.
- *Greenback Greens* (5%): are not as politically active as True Blues, but most willing to express their commitment by a willingness to pay higher prices for green products.
- *Sprouts* (33%): are fence-sitters who have embraced environmentalism more slowly and who are capable of going either way.
- *Grousers* (15%): are uninvolved or disinterested in environmental issues, cynical about their ability to affect the environment, and believe that green products cost too much or they are too busy to shop green.
- *Basic Browns* (37%): are essentially unconcerned about the environment - they don't care about environmental and social issues and believe that buying green products and/or recycling cannot make a difference.

These figures point out that environmental attitudes vary across the shades such that the deeper the shade of green is, the more the willingness to make green purchasing decisions is. It also turns out that even though green products do not appeal to every consumer in the market, 15% to 48% of the entire consumer market could be attracted to green products, depending on certain factors (e.g., product category and perceived benefits).

The red flag here is that there is a big problem that most of such surveys do not bring to light: Under what conditions are consumers willing to make a greener purchase? Simply put, even the deepest green consumers no longer buy green products just to help the planet. They would pick the greener products if these products are at least as good as the brown products, if these products do not require them to change their habits, if they can buy these products where they currently shop, and ideally if these products have some other additional benefits beyond being green - that they last longer, look better, save money or will be perceived by others as cool. The early green products that had gathered dust on the shelves of stores (or that were scrapped) were doomed to failure because consumers almost never select products that require sacrifices on performance, convenience, costs or comfort to help the environment. This is demonstrated by the experience of the Think Mobility electric vehicle of Ford Motor Company. The company launched their highly publicized two-seater, plastic-bodied electric car ‘the Ford Think’ in the late 1990s. The Think was expected to be a market hit, but late in 2002 the company announced they were pulling the plug on the vehicle. The reason was simple: The vehicle required drastic changes in the driving behavior - it required six hours of recharging after only a 53-mile city driving with few recharging locations- and was too inconvenient[8] . For companies to take green to scale, the green products they offer must fulfill consumer needs beyond what is good for the environment because consumers are mostly unwilling to compromise on traditional product attributes

[8] J. Duffy, “Why this isn’t the car of tomorrow,” *BBC News*, 8 October 2002.

such as price, quality and convenience. When it comes to make a trade-off between needs/interests and environmental benefits, the environment almost never wins.

This can be viewed as a high bar - so high that not many products can clear it. The good news in today's green marketplace, on the other hand, is that such differences have been blurred and a plethora of green products are now designed to the point where they are superior over their brown counterparts from many aspects. Many green products are now on the top of consumers' shopping lists because they simply perform better than brown products, they help to protect consumers' own health and that of their children, save money on bills, and so on. A close look at green products that have succeeded in the market over the past decade reveals that many green products can now attract potential consumers on the basis of at least four benefits they offer: Performance and convenience; efficiency and cost effectiveness; health and safety; and symbolism and status. These benefits appeal to all consumers in the marketplace - not just the greenest ones on the fridge of society - and they are the reasons why many green products are preferred over their conventional counterparts nowadays.

1.3.1.1 Performance and convenience

Which detergent would clean better, a regular laundry powder or a hypoallergenic powder that does not contain phosphates? Until quite recently, the answer to such a question would be pretty simple; the regular detergent. This is simply tied to the early green products that did not perform as well as their conventional alternatives and were not a good value - as a matter of fact they were expensive. For example, non-phosphate laundry detergents introduced back in 1970 left clothes looking dingy and smelling stale. Early compact-fluorescent light (CFL) bulbs used to blink as switched on, have a harsh flickering tone and buzz during operation, and did not fit most of the light fixtures. First low-flush toilets were quite unsatisfactory, having problems with high flush volumes, frequent double flushing and flapper leaks. Last but not least, multi-grain cereals that were touted as healthy or nutritious ended up tasting like cardboard. Those products all failed to live up fully to their green boasts and for many shoppers “green” was equal to “worse”. That is to say, green shopping choices simply meant to be making sacrifices in quality, performance and/or convenience.

Today, however, a growing selection of products are designed to deliver convenience and quality, while their materials/ingredients that could harm the environment during manufacture, use or disposal are being phased out. For example, energy efficient, front-loading washers clean better and are gentler on clothes compared to conventional top-loading washers. Energy saving light bulbs are compact, available in a wide range of shapes to fit in more fixtures, throw a softer glow and need infrequent replacement - so the only difference consumers notice will be a drop in their electricity bills. Hybrid cars require fewer refueling stops as well as granting their drivers the convenience of free parking and allowing single-occupant access to HOV or carpool lanes. Timberland’s Earthkeepers® boots, made from recycled material and organic cotton, are high quality, durable/sturdy, comfortable, lightweight and stylish. Milgard’s insulating SunCoat Low-E® windows not only cut heating and cooling losses, but also reduce the harmful ultraviolet rays fading carpets and furniture[9] . Reusable canvas shopping bags are easier to carry and can handle heavy loads.

The bottom line is many consumers that were not ready to give up their “brown” mindset once are now turning to green products because these products promise a higher performance and offer inherent convenience benefits. Today, nearly 80% of consumers say that green household cleaners are as effective as conventional cleaners, and more than one-third of the U.S. consumers are purchasing natural cleaning/personal care products, organically produced foods, compact-fluorescent

[9] http://www.everclearwindows.com/milgard-aluminum-windows.html, accessed May 28, 2011.

lambs, and rechargeable batteries[10] . Green products are no longer hurt by the perception that they are of lower quality or inconvenient - meaning that they no longer present a substantial impediment to green purchases. Instead, they play a pivotal role in motivating green shopping choices for a substantial number of consumers.

1.3.1.2 Efficiency and cost effectiveness

In the wake of increasing energy prices, calls for water conservation and threat of America's foreign oil dependency, appliance and automobile makers have been gearing up to offer greener products. The inherent benefit of these products is their potential energy and resource efficiency leading to cost effectiveness. For instance, according to Energy Star®, a joint voluntary labeling program of the U.S. Environmental Protection Agency and the U.S. Department of Energy designed to identify and promote energy-efficient products, Energy Star® rated washers use 30% less energy and at least 50% less water than do traditional washers, while Energy Star refrigerators use at least 15% less energy than do standard models. Likewise, CFL bulbs use about 75% less energy than standard incandescent bulbs and lasts up 10 times longer. Faucet aerators and water-efficient showerheads use up to 30% less water. Thanks to its electric power hybrid technology, the Toyota Prius uses up to 50% less fuel than an equivalent vehicle[11] . In other words, such products have the ability to help families save on recurring expenses. They have a downside though; they do not come cheap and it can be deterrent. For example, eco-friendly appliances of Whirlpool can cost anywhere from $\$1,400$ upward depending on the model, or the cost of eco-friendly appliances of Bosch can reach up to $\$1,500$[12] .

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[10] Environmental Leader, "Fast-Moving Eco-Friendly Consumer Goods Appeal to Many," October 2008.

[11] M. Knowling, "The Toyota Prius Hybrid," *autospeed*, 2 July 2002.

[12] C. Tan, "New Incentives for Being Green," *Wall Street Journal*, 4 August 2005.

The question here is whether the up-front premium for energy efficiency is worth it. Indeed, a growing number of cost-conscious consumers today are willing to pay an up-front premium for energy-efficient and/or water-conserving products, because they realize that such products will help them slash energy and/or water bills over the long term. The buyers of the Toyota Prius® have been lining up on waiting lists for months and even paying thousands over sticker for the car, and it is fuel savings behind the peak in interest[13] . Thanks to their energy savings and long life, the purchases of premium-priced CFL bulbs top consumers' shopping lists, and they are followed by energy-efficient electronics and appliances, and rechargeable batteries[14] . Apparently, in spite of significant price differences, many cost-conscious buyers are willing to make the conversion to efficient green products, and so interest in these products keeps soaring. In recognition of that, mainstream consumer-products giants from Whirlpool to GE have been rolling out efficient products without a break. A recent high profile example is the Mac mini computers, introduced by Apple in 2010 and touted as the world's most efficient desktop computer, which requires less power than a single energy-efficient CFL bulb[15] . As a ripening fruit of this trend, inefficient brown products are being phased out and their efficient counterparts are taking over their place day by day.

1.3.1.3 Health and safety

In 2008 organic food sales grew by 15.8% to reach $22.9 billion, while sales of organic non-foods (e.g., organic fibers, personal care and pet foods) grew by 39.4%

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[13] "Rising Consumer Interest in Hybrid Technology Confirmed by Maritz Research," PRNewswire, 5 January 2006.

[14] http://www.nmisolutions.com, accessed May 25, 2011.

[15] http://www.apple.com/environment/progress, accessed May 25, 2011.

to $1.6 billion although the overall economy was losing ground[16] . In 2009, the sales of nontoxic cleaning products of Seventh Generation (e.g., dishwashing detergent and paper towels) fetched $150 million, up 20% from the previous year[17] , despite bigger-name rivals, such as Clorox and SC Johnson, entering the market. With a sales growth of 16% in the fourth quarter, Swedish natural cosmetics Oriflame concluded 2008 the best year ever[18] . These figures indicate that many green products have surprisingly weathered the recession; they do not have the air taken out of them by the ongoing economic hardship. Consumers are pulling their money belts quite tight, but the sales of many green products remain strong anyway. This is no surprise indeed - thanks in part to the health and safety benefits these products bestow.

Fueled by a steady stream of news reports on global warming, widening ozone holes, exposure to radiation owing to the devastating earthquake and tsunami in Japan, the BP oil spill in the Gulf of Mexico a year ago, the recall of peanut butter products contaminated with Salmonella, and many others, consumers increasingly fret about their own health as well as that of their children. Concerns over health risks from toxic chemicals, food safety and pollution in everyday products have driven consumers to think twice about the products they buy. Can they be trusted? Is it safe for consumption for the entire family? Today, the most preferred household product features include "safe to use around children", "no toxic ingredients", "no strong fumes", and "no chemical residues"[19] . At this point, because a product's safety for the environment

[16] http://www.organicnewsroom.com/2009/05/us_organic_sales_grow_by_a_who.html, accessed May 25, 2011.

[17] L. Burkitt,"Seventh Generation: Protecting Its Green Turf," *Forbes*, 18 January 2010.

[18] http://investors.oriflame.com/files/press/oriflame/1289306-1.pdf, accessed May 28, 2011.

[19] E. R. Stafford, "The Return of Green Marketing," *Green @ Work Magazine*, Sept/Oct 2002.

ultimately means higher water quality, less hazardous waste and air pollution, and toxin-free consumption, green products hold a broader appeal among health-conscious consumers. For example, a growing number of people are willing to pay a premium for organic foods just because they believe organic foods to be healthier and safer[20] . Nontoxic oven cleaners are more preferred than conventional cleaners since the latter are known to be amongst the most toxic household products. What consumers are seeking today is healthy and safe purchases. That is why health and safety benefits of green products have become a key motivator driving the green offerings.

1.3.1.4 Symbolism and status

Green products are “cool”. Once offered under brand names no one had never heard of, green products are now not only mainstream, but they are also chic. In a sense, they have become analogous to the brightly colored awareness wristband bracelets - they show the world that their owners care. Today, many green shoppers go green not to save the planet, but rather to impress their neighbors. When the New York Times® reported the reasons customers cited for buying a Prius®, protecting the environment placed last on the list. Instead, Prius® drivers proudly reported that the main reason for buying the car is that “it makes a statement about me.”[21] People want to be seen relatively more altruistic, and nothing publicly displays that better than driving a Toyota Prius® down the street, or carrying canvas tote bags in shopping. In the same vein, when celebrities such as Leonardo DiCaprio, Cameron Diaz and Tom Hanks are photographed behind the wheel of a Prius®, despite being able to afford more expensive oversized sport utility vehicles, it functions as a self-promoting billboard: “We are caring individuals.”

[20] “Organic and Ethical Foods,” Mintel Marketing Intelligence, 29 May 2001.

[21] M. Maynard, “Say ‘Hybrid’ and Many People Will Hear ‘Prius’,” *The New York Times*, 4 July 2007.

Green shopping is also motivated by social status. When shoppers are on the street where they are being watched by other shoppers, they are more likely to go green, and forgo price, comfort or convenience for the sake of higher-status green products. Green products show that their owners are willing and able to incur the higher costs of buying a green product, even if it is inferior for personal use compared to its brown counterpart. In other words, green products signal that their owners can afford such acts of "self-sacrifice" for the public good: They are caring and able to pay a premium for that privilege. For instance, "[d]riving a luxurious non-green car, like a Hummer, communicates one's wealth, but also suggests that the buyer is a selfish and uncaring individual who is concerned primarily about his own comfort rather than the welfare of society. Driving a hybrid, like a Prius, not only displays one's wealth as it costs many thousands of dollars more than a conventional but highly fuel-efficient car, but also signals the owner cares about others and the environment."[22] This example can easily be adopted to other green products like energy-efficient washers, organic vegetables, cloth nappies, and energy-efficient televisions. It is the social standing boosted by these products that encourages shoppers to change their shopping lists and choose green products.

1.3.2 The Share of Green Governments, Laws and Regulations

The drive towards "green" has taken its toll on almost every government; their legislative agendas increasingly advocate for environment. Governments around the world grapple with how to kick-start their economy under the dark cloud of recession, and "going green" turns out to be a potential way out. Right now, governments are seeking to provide a massive push for more green investment. They keep rolling out green projects to harness the power of going green which can not only provide new

[22] A. Vaughan, "Shoppers choose green products to improve social status, says study," *guardian.co.uk*, 29 March 2010.

markets - while the old ones are already evaporating - required to grow the economy, but also address the environmental protection. For instance, the 2009 Economic Stimulus Package put forward by the Obama administration includes hundred billion dollars for "green-collar jobs" that require skilled labor force to work on producing green products, organic farming, recycling, reusing and renewable energy construction. It also provides a 30% tax credit for investments in factories that manufacture energy efficient products, batteries, solar panels and wind turbines. Other countries are not to be left behind as they are following the suit. In order to extend a helping hand to green companies, the French government, for example, has pledged to invest heavily in the form of tax breaks and grants for green R&D as a part of their Grenelle de l'Environnement et de la Mer policies. Likewise, the German government's product take-back initiatives reward companies for finding ways to reduce packaging and integrate design for disassembly, reuse and recycling into their product design. These governmental efforts do appear to be a driving force in going green. Managers of companies like American Airlines, Bell Atlantic, HP and Coca-Cola are reacting to such initiatives - in part to help lower/split the initial high costs of R&D - by making investment in green R&D part of their overall business strategies and putting greener products in the market.

Governments' environmental efforts are not solely confined to economical growth packages. Today, developing green products is no longer considered as a value add-on practice because it is stringently compulsory by environmental laws and regulations. There are increasing regulations and laws passed by governments nowadays that put greater pressures on companies to adhere to the environmental standards in their operations. Among the first out-of-box regulations: the Extended Producer Responsibility, Restriction of Hazardous Substances (RoHS), Waste Electrical and Electronic Equipment (WEEE), and Eco-design for Energy-using Products (EuP). For instance, in 2009 the Obama government announced new Corporate Average Fuel Economy (CAFE) standards - another green directive aimed at improving the average fuel economy of cars - that require auto manufacturers to sell vehicles that must get an average of 35.5 miles per gallon by 2016[23] . Various countries along with a number of U.S. states are adopting such regulations and creating their own policies in the absence of federal action. In 2007, for example, San Francisco approved legislation to ban supermarkets from using non-recyclable plastic grocery bags at checkouts[24] . Faced with a European Union directive on hazardous chemicals, Apple Computer reworked its entire product line by 2008 and phased out a range of persistent toxicants and other dangerous materials[25] . Owing to the requirements for toxic emission reporting that put companies under close scrutiny, tons of toxic emissions have been eliminated in many countries.

Each year that goes by, more and more regulations are being issued by governments, and more importantly the days when non-compliance with environmental regulations goes unnoticed are long gone. Should they fail to comply, companies can be required to bear significant costs in terms of fines, penalties, product recalls and negative publicity that can damage their brand image. For instance, in 2008, Home Depot agreed to pay $1.3 million penalty, and implement a comprehensive, corporate-wide compliance program to resolve alleged violations of the Clean Water Act, following the discovery of storm water pollution at more than 30 construction sites in 28 states where new Home Depot stores were being built[26] . More recently, Pepsi Cola appeared in the news, agreeing to pay $1 million penalty for violation of California's Proposition 65 by

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[23] J. Eilperin, "Emissions limits, greater fuel efficiency for cars, light trucks made official," *Washington Post*, 2 April 2010.

[24] J. M. Glionna, "San Francisco thinks green: Plastic grocery bags banned," *Los Angeles Times*, 28 March 2007.

[25] "Apple and the Environment," *Apple Inc.*, 15 January 2010.

[26] Environmental Leader, "Alleged Clean Water Act Violations Cost Home Depot," February 2008.

failing to warn consumers that the labels on bottled soft drinks contained lead[27] . These settlements can spell trouble for even big-name companies. The impact of failure to meet regulations can be staggering and long lasting; it can result in products being banned for sale or delays in demonstrating compliance can slow/halt a product launch. Today, nearly 75% of corporate managers say political and regulatory environments are their top concerns[28] and that is why they have started to concentrate on the environmental impact of their products and operations that they will be held responsible for any damage.

1.3.3 The Response of Manufacturers

At the Coca-Cola Retail Research Council Global Forum, in Beijing, Tesco's chief, Sir Terry Leahy, said "We must go green."[29] Many companies including Starbucks, Pepsi Cola, The Body Shop and Carrefour stress environmental stewardship in their mission and/or vision statements. On its company website, SC Johnson, producer of a variety of products from food storage products Ziploc® bags and Saran Wrap® to Raid® pest killer, writes: "From the ingredients in our products, to the way we run our factories, we're committed to working every day to do whats right for people, the planet and generations to come."[30] It does appear that green sits at the head of the board room charts nowadays. There is a compelling business case for green, and savvy managers of companies are taking steps to reduce the environmental impacts of their products at a deeper level - as never before. Going green to save the planet is

[27] http://articles.latimes.com/2006/apr/22/local/me-soda22, accessed June 2, 2011.

[28] Environmental Leader, "Risk Managers Worry the Most about Political/Regulatory Environments," April 2010.

[29] S. T. Leahy, "Tesco chief: 'We must go green'," guardian.co.uk, 3 September 2008.

[30] http://www.scjohnson.com/en/commitment/overview.aspx, accessed June 2, 2011.

no longer a pitched battle between companies and governmental regulations or radical environmentalists. Today, addressing green is not a matter of regulatory compliance that adds nothing but additional costs. Rather the opposite in fact. It is all about doing better and for that reason environment-related actions of many companies undertaken recently are not solely limited to those required to meet regulatory requirements. Big-name companies like Wal-Mart, Toyota, GE and Shell are often cited in business articles and reports nowadays with their green products/operations because they are decisively and effectively committing to going green and “winning” by reaping its benefits.

1.3.3.1 Opportunities in green market and competitive advantage

Leading-edge companies are beware of the opportunities in green market that are ripe for picking. They no longer consider going green and doing well financially as an either-or proposition but instead attempt to achieve both goals simultaneously. Green practices are considered to be better for a company’s bottom line because addressing green proactively in operations can open new markets and drive new revenue streams, reduce the cost of raw materials/energy, strengthen public reputation, and avoid business risks (e.g., environmental liabilities). Besides, companies whose “environmental strategies provide added degrees of freedom to operate, profit and grow” can seize competitive advantage by “[getting] ahead of the Green Wave.”[31] In today’s business world, green is beginning to become a promising part of value creation, and entering into the equation. Many companies are seeking to turn to green by fully identifying the risks posed by their products and manufacturing processes, and making them greener by design to improve efficiency, reduce energy use/waste and lower emissions - in essence to improve corporate bottom line.

[31] D. Esty and A. Winston, “Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value and Build Competitive Advantage,” Yale University Press, 2006.

In almost every industry (e.g., textiles, high-tech and automobiles) companies are seeking to participate in the growing green market and are in a race to pursue environmental practices in their operations and design green products - not to be left behind a shrewd competitor. For instance, in 1995 True Textiles developed a new group of fabrics called Terratex® - made from 100% post-consumer recycled polyester or from corn - that are inherently less toxic, and easier to recycle or dispose of than conventional fabrics. It helped the company improve its branding and reputation, and develop a growing revenue stream, as well as offering reduced costs for raw material, water and energy in manufacturing. In 2006 the company estimated that the Terratex® delivers recurring savings of around $300,000 each year[32] . Likewise, in 2008 Clorox developed the Green Works® line - a line of five nonsynthetic cleaning products. It helped the company grow the market for green products and capture a larger market share. By the end of 2008, Green Works® enjoyed a 42% share of the U.S. natural cleaners market, and is estimated to generate $200 million revenue each year[33] . These stories of success are big tangible reasons why many companies as diverse in size and scope as Apple, HP, SC Johnson, and P&G are increasingly embracing green practices and looking to launch new green products into the market.

1.3.3.2 The role of supply chain partners

Nearly every day, more and more retailers step up their game when it comes to their green efforts to help the environment. In a move to improve their overall reputation, they set a series of goals to eliminate or at least reduce any harmful impacts of the products displayed on their shelves. Some retailers get engaged in an effort to encourage

[32] T. Greiner, "Healthy Business Strategies for Transforming the Toxic Chemical Economy," *Clean Production Action*, June 2006.

[33] Environmental Leader, "Clorox's Green Line Takes 42% Of Natural Cleaners Market," January 2009.

suppliers to redesign their products in a more environmentally-friendly way by offering them incentives, while others choose laying down the law in order to force them to take corrective action. For example, in October 2008, Lee Scott, the CEO of Wal-Mart, handed over a directive to 1000 suppliers in China: Reduce waste and emissions; decrease packaging costs by 5% by 2013; and improve the energy efficiency of products supplied to Wal-Mart stores by 25% within three years[34] . More notably, Scott delivered a stern message: “Go green the Wal-Mart way or Wal-Mart will take its business elsewhere.”

Wal-Mart is not the first retailer to put forth supplier requirements that push forward innovation in green products, and environmentally friendly and socially responsible operations. IKEA has sought to use (a) wood from forests certified as responsibly managed that replant and maintain biological diversity, and (b) only recyclable materials for flat packaging since 1992[35] . In like vein, in October 2009, global retail giant Tesco announced suppliers must reduce carbon footprint 30% by 2020, and set the goal of being carbon neutral in its stores and supply chain operations by 2050[36] . Best Buy, Marks and Spencer’s, CVS and Home Depot are just some of the noteworthy examples of other retailers that ask their suppliers to redesign a product using safer materials/components, otherwise they will choose to do business with others. In order to improve the odds of continuing to work with these retailers, suppliers aggressively endeavor to develop green alternatives. Since suppliers work with many different

[34] http://gogreenstips.com/tag/green-supply-chain, accessed June 2, 2011.

[35] http://www.ikea.com/ms/en_US/about_ikea/our_responsibility/forestry_and_wood/index.html, accessed June 6, 2011.

[36] http://www.thegreensupplychain.com/NEWS/09-10-19-1.PHP, accessed June 6, 2011.

retailers, their individual efforts create a ripple effect across the entire market, and more supermarket shelves are allotted to green products.

1.3.4 Social Media Turns to Green

In a now-classic Super Bowl ad of 2006, in a spot for the Ford Escape Hybrid®, Kermit the Frog is seen struggling his way through mountain biking, kayaking and mountain climbing with his trademark tune "It's not that easy being green" playing in the background, but then encountering a hybrid Escape® sports utility vehicle in the mountainside, and in a twist, changing his tune with "I guess it *is* easy being green." Nissan launched a similarly catchy polar bear ad during the 2010 NFL season debut, where a polar bear treks from the Arctic to thank a Nissan Leaf® owner for helping to save his home. On the billboard at the exit of the Lincoln Tunnel in Manhattan, drivers see the Toyota Prius® slogan: "Miles and miles and miles per gallon." Johnson & Johnson's skin care line Aveeno® built its ad campaign on the "science of active naturals" ingredients like soy, oats and shiitake mushrooms. Along with these ad campaigns, many other big-budget campaigns such as "Go Green Samsung" of Samsung, "Ecomagination" of General Electric, "Human Energy" of Chevron and "Owl spot" of Bosch have been running on prime time television to address brands' environmental credentials lately.

Social media has turned to green and almost every brand has jumped on this green bandwagon. Green has become the new black in the ad world; businesses have begun to use social media smartly for marketing, building their brand reputation and promotion. According to TNS Media Intelligence, within the just three-month span of 2007 (from March to June), "marketers shelled out a combined $18 million on green-focused TV ads."[37] Today, a multitude of hip green products are widely being touted by an

[37] http://www.usatoday.com/money/advertising/2007-06-22-cannes-green-usat_N.htm, accessed June 6, 2011.

increasing number of TV commercials. A bumper crop of green stories are being covered in the "Business of Green" section of the major national dailies such as the New York Times® and the Washington Post®, and featured on the covers of mainstream magazines like Newsweek® and Vanity Fair®. In addition, publishers are increasing their editorial coverage about the business stories on environment, and spawning numerous new "eco" issues and publications on how families can make green a part of their daily lives (e.g., National Geographic's Green Guide® magazine). The heightened interest of companies has also led to a plethora of websites and blogs devoted to green products. These mediums such as SustainableBusiness.com, TreeHugger.com, GreenBiz.com, Mr. Green, Sustainablog and Ecorazzi empower visitors to search and harvest the latest highly rated articles on new green products and green living tips, and share them with other information-seeking aware consumers.

Meanwhile many Hollywood celebrities are dedicating their time to advocate for the going green campaigns and walking their green talk. For example, Oprah Winfrey deemed "Going Green" worthy of a show in April 2007, asking people "to implement just one green idea to help the fight against global warming."[38] Madonna composed the song "Hey You" written for the "Live Earth" concert. The November/December 2006 issue of the The Green Guide® magazine was guest edited by Meryl Streep. Robert Redford and Leonardo DiCaprio have been board members of the Natural Resources Defense Council that works against pollution and habitat destruction, and promotes actions to mitigate global warming and increase the use of renewable energy. All these daily messages and images that fan green lifestyles indeed serve to a single purpose; raising the awareness and attractiveness of green products. Polls consistently indicate that the biggest obstacle when buyers consider going green is their lack of awareness

[38] http://www.oprah.com/world/Its-Easy-Being-Green_1, accessed June 4, 2011.

of green product alternatives and/or benefits of these products[39] . That is why these mediums of “green media” have been proving invaluable to the spread of green products across prospective buyers.

1.4 Should Companies Develop Green Products?

Until quite recently, companies contemplating a new product launch typically looked only in one direction; superior traditional quality. But times have changed. Thanks to consumers’ insatiable desires for environmentally benign choices, potent regulatory forces and business opportunities, the pool of green products is growing at a rapid rate and green companies are nipping at the heels of many mid-tier and premium “brown companies”. They are losing share to these green competitors, and their managers increasingly face a strategic conundrum: Should they tackle the threat head-on by expanding their product lines with green alternatives, knowing that can destroy the profits of their brown products in the short term but improve their bottom line in the long term? Or should they hold their product line, hope that interest in green shopping is just a fad, and in the meantime lose their potential consumers who might never come back? Even though all those alternatives can turn out to be unpalatable from time to time, company managers are often tempted to launch greener brands not just to fend off green competitors in the marketplace but also to open up a new green market that exhibits high growth potential.

In its best applications, companies can return in remarkable successes from this approach. For example, Clorox was able to cash in from its Green Works® line by the end of 2008, and the tailwind had encouraged them to launch more green products: The company introduced biodegradable cleaning wipes in January 2009,

[39] http://sloanreview.mit.edu/the-magazine/2009-summer/50415/what-the-%E2%80%98green%E2%80%99-consumer-wants, accessed June 2, 2011.

and non-synthetic detergents the following June where they run into rival P&G[40] . Not properly executed, such success stories can turn out to be the exception though, and it may have detrimental impact on these companies. Greener products, in essence, are offered to win back consumers that have switched to a green rival. They can also help grow the green category as a whole, draw attention to green products and build consumer awareness. On the other hand, once deployed, these products can also rob significant sales from a company's own profitable brown offerings. More importantly, companies can find themselves in a battle on two fronts when they launch a green alternative at the time of selling a brown product. This may siphon away the attention of company management and divide company resources as well. Therefore, launching a greener product causes a company face with a dual challenge: It must ensure that the greener product has a keen grasp of green consumers' preferences (so it does not miss the mark with green consumers), while guaranteeing that it does not cause the company fall short for its bottom line as a result of cannibalization or management distraction. A company must diligently determine the value, appeal and accessability of its potential greener products and weigh the effects of cannibalization before offering them.

1.5 Dissertation Focus

Green product development has not lived up to the expectations of many managers and environmentalists. Moving into the green market has not fulfilled its initial promise, because it is almost always difficult for companies to choose and implement a profitable green product strategy. Indeed, companies that have been trying to forge a path to green product development have found themselves in a struggle to deal with a critical issue: There does not exist a *one-size-fits-all* strategy when it comes to green. This may seem like common sense, but such wisdom seems to elude most company managers

[40] R. Nidumolu, C. K. Prahalad and M. R. Rangaswami, "Why Sustainability Is Now the Key Driver of Innovation?," *Harvard Business Review*, September 2009.

who still insist on pushing out product design/development efforts that are variously too technical or too vague. Companies need more than inspiration: They need information and, more important, context to evaluate alternative green product strategies and the underlying rationale behind each of them, and so to fully understand and appreciate how choosing a green product strategy will benefit them. For starters, they need to ask themselves a wide array of questions regarding the strategy choices such as “What is our strategic goal; broadening appeal to new consumers, gaining green credibility, and/or bringing in new green capabilities?, “How substantial is the green consumer market for the company?”, “Can we sell the green product to our current consumers?”, “Can we differentiate our existing products on the green dimension?”, “Do we have the resources and an understanding of what it means to be green in the industry?”, and “How can we beat our competitors in the green market?” It is clear that addressing such questions in their quest for going green by means of offering greener products should make the choices and trade-offs clearer, and help companies formulate a strategy suited to their objectives and market space.

Talking about “green product development” turns out to be anything but not simple. Focused, more nuanced approaches are needed to ensure that a company’s green product strategy is not a *one-size-fits-all* affair and that its concern about the environment matches that of its customers. Based on that this research focuses on the analysis of green product strategies companies can use to get into the increasingly green-aware marketplace. The first project (Chapter 4) is built upon two broad strategies of developing green products - Accentuate, and Architect - that companies can use to align their green goals with their capabilities. These strategies are introduced and described by Unruh and Ettenson (2010) based on 10 in-depth case studies of consumer product and industrial companies that were moving into the green market. An Accentuate strategy involves highlighting existing or latent green attributes in a company’s current product portfolio. On the other hand, if a company has substantial new product development skills and assets, it can architect new offerings - build them from scratch. Unruh and Ettenson (2010) suggest that which strategy is best depends on how “greenable” a company’s existing portfolio is and how advanced its green product development capabilities are. The companies must align their green strategy with their existing product(s) and devote or develop the resources and capabilities needed to achieve their strategic goals. The first project queries whether the level of a company’s current product’s green quality content and/or its green process capability are the only moderating features in making a choice between these strategies.

The second project (Chapter 5) builds upon the segmentation of the environmental marketplace devised by GfK Roper Public Affairs & Media based on public opinion surveys in 2002 and 2007. The study underscores that consumers have different interests and motivations when it comes to viewing their purchases through a green lens. Categorizing consumers into meaningful groupings that describe and predict their behavior and predilections when shopping - rather than classifying according to conventional demographic factors such as age, residence and income - can obviously help companies to smarten up their environmental strategies, and to determine which products to develop and how best to target them. Asserting that values, tastes and preferences are more likely to influence consumers’ purchases than their demographic traits are, the second project focuses on a company recognized for its brown offering (and traditional expertise) and examines how the existence of many shades of green consumers affects the company shape and assess two alternative green product development strategies. The strategies analyzed in this project includes greening an existing brown product by making small adjustments in raw materials, packaging and so forth, and developing an entirely new product from scratch with significantly less environmental impact.

1.6 Organization of Dissertation

The remainder of this study will be structured as follows. Chapter 2 reviews the current literature on product design in vertically and horizontally differentiated markets. Chapter 3 outlines alternative green product strategies that are widely used by companies to successfully launch themselves into the green product realm, and discusses the underlying principles and reasoning behind each strategy, as well as the different market conditions under which they work best. It concludes with a proposed framework for green product strategies. Chapter 4 introduces and develops a stylized model for analyzing two green product strategies - Accentuate and Architect. Chapter 5 analyzes product positioning decisions of a single firm that contemplates targeting a brown, green or greener product to different consumer segments with varying environmental attitudes. Chapter 6 underlines overall findings and contributions of the research, and finally discusses future research directions.

CHAPTER 2
LITERATURE REVIEW

In a marketplace of consumers that differ in their willingness to pay and/or have heterogenous tastes, companies are often tempted to launch a menu of offerings to serve those different market segments and calibrate those offerings to their own strategic advantage. The overall consumer market is typically segmented by consumers' propensity for quality, and company managers, in response, usually roll out different quality-price bundles to cover their target consumer market as completely as possible. For example, in the face of economic strains that cause consumers to trade down to low-end products (lower quality-price bundles), many premium brand companies launch a "step-down" version of their brand so as to avoid losing market share to low-end rivals. Consider the car company Toyota which has a diverse business portfolio with its existing line of cars as well as brands such as Lexus® and Scion®. Toyota created the Lexus® brand to target the luxury-car market segment, while the purpose of offering Scion® was to attract the attention of youth market segment by introducing them to a relatively cheaper but a radically designed car. The results of this product line design are the creation of two brands that both offer a unique lineup of cars that target the luxury and youth market.

This approach can help a company fend off low-end rivals while allowing its high-end brand (high quality-price bundle) to stay above the fray. Unfortunately, it is easier said than done. Designing a line of products is very hard to pull off mainly due to the threat of cannibalization within the product line. To be sure launching a variety of products makes sense, companies must carefully position and price their products so that the low-end products will not draw consumers with high willingness-to-pay away from the high-end products. To prevent cannibalization, the companies can deliberately lessen the value or appeal of their low-end products to the high-end products' target segments, and can even need to disable existing product attributes and withhold marketing support from the low-end products. Each product in the product line should offer a sufficiently differentiated proposition, and because price and quality are the two dimensions that define different products in a product portfolio, it is critical to analyze these two aspects.

2.1 Product Line Design in Vertically Differentiated Markets

It is well recognized that one of the crucial decisions for a firm is to develop product designs and select products in its product line under the threat of cannibalization. Product designs are usually defined by multiple attributes that can be grouped into two main categories: vertical and horizontal differentiation dimensions. Vertical differentiation captures the product performance or quality as a well-established driver of consumer willingness-to-pay, whereas the horizontal differentiation represents the feature choices of product design. Unfortunately, market structure models that combine both vertical and horizontal differentiation in consumer preferences are mathematically intractable, and only part of the results can be obtained analytically. Related to this point, in order to present analytical results, the majority of past literature has intentionally examined the markets that are either vertically differentiated or horizontally differentiated. In addition, those research papers have alternatively made assumptions about market coverage (e.g., all consumers must buy one and only one product), restricted the types of products (e.g., development intensive products dominated by fixed costs or marginal cost-intensive products for which the development cost is a relatively small portion of the overall cost of product quality), or focused on component sharing across different products. We start by reviewing prior work on vertically differentiated markets and the reader is referred to Lancaster (1990) for a comprehensive review of earlier marketing models that deal with vertically differentiated products.

2.1.1 Product Design with a Single Attribute

Mussa and Rosen (1978), O'Keeffe (1980) and Katz (1984) are the first among corresponding research papers that restrict the market behavior into vertical differentiation and analyze the price-quality policies of a single profit-maximizing firm that targets a line of products to different consumer segments. In these studies, the term "quality" refers to the level of a single attribute or some scalar metric representing a vector of attributes (e.g., variety, functionality, and/or reliability). Mussa and Rosen (1978) study vertical product differentiation with respect to a single continuous quality-type attribute in a market with heterogenous consumers. They consider a single firm that sells one unit of a differentiable product to each consumer with varying preference intensity for quality, q. The underlying utility function is considered to be linear in $\theta > 0$ - measuring the intensity of a consumer's preference for quality. Consumers' valuations of quality vary in proportion to θ, so that preferences of the set of potential consumers are described by the distribution of θ; a density $f(\theta)d\theta$ defined on the interval $[\underline{\theta}, \overline{\theta}]$. The product in consideration is a marginal cost-intensive product. The marginal cost of production at any quality level, $C(q)$, is assumed to be constant, and unit production cost is given as an increasing convex function of quality, that is, $C'(q) > 0$, $C''(q) > 0$ for all $q \geq 0$. With this model, they examine the case of two types of consumers, distinguished by their intensity of quality preference, θ_h and θ_l such that $\theta_h > \theta_l$.

The efficient (surplus-maximizing) solution of their model is characterized by two features. Firstly, each consumer type selects the quality for which $C'(q_i) = \theta_i$ ($i = h, l$), i.e., where the marginal cost of quality is equal to preference intensity. Secondly, for that quality, each consumer type pays exactly the unity of producing the chosen product type, i.e., $p_i = C(q_i)$ ($i = h, l$). Under perfect discrimination, where the two market segments are perfectly separable, the firm will offer these qualities, but at higher prices that help extract all consumer surplus from each consumer type. In case, where the firm lacks the capability for prior sorting of its consumers into classes, it can segment the market to its advantage by structuring its offerings in a manner that induces self-selection by consumers among quality types with varying price-cost margins. The firm can accomplish this by imposing self-selection and participation constraints. Given $\theta_h > \theta_l$

and the number of consumers N_i in each group, the total profit of the firm is then written as

$$\pi = N_l[\theta_l q_l - C(q_l)] + N_h[\theta_h q_h - q_l(\theta_h - \theta_l) - C(q_h)], \tag{2–1}$$

with first-order conditions:

$$\begin{aligned} C'(q_l) &= \theta_l - \frac{N_l}{N_h}(\theta_h - \theta_l), \\ C'(q_h) &= \theta_h. \end{aligned} \tag{2–2}$$

The implications of this model are as follows: (a) The price charged to the high valuation segment lies between the competitive price and the perfectly discriminating price. The firm sells the same quality as a competitive firm to the high segment, but the self-selection constraints require the quality offered to the low value segment be lowered, by the amount $N_1(\theta_2 - \theta_1)/N_2$. This segment is offered a quality lower than any that would appear under competition or perfect discrimination. (b) The altered price-quality combinations imply more low-quality goods sold relative to a competitive setting. The results derived by O'Keeffe (1980) and Katz (1984) later on turn out to be similar to those of Mussa and Rosen (1978).

Moorthy (1984) examines the product line design problem for a firm that sells a menu of vertically differentiated products. He presents a model for determining the optimal product line selection and the optimal price of each selected product. The products can be ordered according to their objective quality so that a higher quality product is more desirable than a lower quality product. The firm aims to serve multiple consumer segments that differ in their valuations of quality. Higher-valuation segments derive greater marginal utility from quality, and so they are eager to pay a higher price for a given quality than lower-valuation segments. When the unit production cost is convex in quality and the market is comprised of different segments, it is shown that the firm is better off creating products so that higher-valuation consumers buy higher-quality products at higher prices. He finds that the highest-valuation segment gets its preferred (i.e., surplus maximizing[1]) quality, while the qualities of products aimed at all other segments are distorted downwards and are strictly less than efficient levels. Furthermore, if the cannibalization effect is strong enough, it is optimal for the firm not to serve low-valuation segments of consumers by offering less than efficient number of products. The price of the lowest-quality product is set in such a way that the lowest-valuation consumer gets no value from purchasing the product and is indifferent between buying the product targeted to it and not purchasing any product at all. This is in line with the results obtained by Mussa and Rosen (1978), who study a similar model with a continuous distribution of consumer valuations.

The models introduced by Mussa and Rosen (1978) and Moorthy (1984) constitute a strong building block in developing the the theory of product line design in the face of a segmented consumer market. As an alternative approach to product line design problems, Dobson and Kalish (1988) propose a mathematical model that determines how a single firm should position/reposition and price a line of substitute products. In their model, the consumer market is composed of m different consumer segments of various sizes, each containing homogeneous consumers. Furthermore, there exists a set of n potential products to be launched. Each consumer provides a measure of the value of each potential product to him (i.e., reservation price), and he chooses the product that provides him with his preferred quality. Each potential product has a constant unit production cost that can vary across products, and the firm incurs a fixed cost associated with each product offered.

[1] Maximum surplus refers to maximum difference between the reservation price (or consumers' maximum willingness to pay) and actual price.

The proposed mathematical model is given as follows:

$$\text{Maximize} \quad \sum_{i=1}^{m}\sum_{j=0}^{n} N_i(p_j - c_j)x_{ij} - \sum_{j=1}^{n} F_j y_j \tag{2–3a}$$

$$\text{subject to} \quad \sum_{j=0}^{n} x_{ij} = 1 \quad \forall i \tag{2–3b}$$

$$x_{ij} \leq y_j \quad \forall i, j \tag{2–3c}$$

$$\sum_{k=0}^{n} (V_{ik} - p_k)x_{ik} \geq (V_{ij} - p_j)y_j \quad \forall i, j \tag{2–3d}$$

$$p_0 = 0 \tag{2–3e}$$

$$x_{ik}, y_k = 0, 1 \quad \forall i, k \tag{2–3f}$$

where

V_{ij} the reservation price of the ith segment for the jth product,

N_i the number of individuals represented by segment i,

c_j the unit cost to produce product j,

F_i the fixed cost incurred if product j is offered at all, where

i ranging from 1 up to m indexes the segments,

j ranging from 0 up to n indexes the products, and

y_j equals 1 if product j is offered; 0 otherwise,

p_j the price of product j,

x_{ij} equals 1 if segment i is assigned to product j; equals 0 otherwise.

In this modeling framework, they develop a heuristic algorithm to solve the problem of how many products to introduce, where to position them, and how to price them so as to maximize the total profit of the firm.

Moorthy and Png (1992) extend the single-period product line design problem to a two-period setting and analyze the trade-off between simultaneous and sequential product introduction strategies. They consider a single firm that faces two consumer segments, namely high-valuation h and low-valuation l segments. Consumers agree on their ranking of available products, but differ in their willingness to pay - consumers in high segment value quality more highly. The heterogenous preferences of consumers for quality arises the necessity of a differentiated product line, and the firm can follow two strategies to offer these differentiated products. Under the simultaneous strategy, the retailer offers two differentiated products at once, but the lower quality product would cannibalize the demand for the higher quality model. At this point, lowering the quality of low-end product, whereas reducing the price of high-end product may alleviate the cannibalization. As an alternative strategy, the firm can increase the quality of low-end product, but force consumers of low-end product to wait before they can buy the product by delaying its release date. The downside of the sequential strategy is that the profits from the low-end product would arrive later. Therefore, the firm has to weigh the advantages of a sequential strategy against the disadvantage of postponing the profits from one of the products in choosing between simultaneous and sequential product introduction strategies.

In this model, it is assumed that the firm has available technology to introduce two products simultaneously. It can only sell over two periods, and can commit in the first period to subsequent prices and qualities. On the demand side, the firm faces a deterministic and stationary consumer demand, and they assume that consumers leave the market forever once they have purchased a unit of product regardless of its quality. The consumers' utility functions are assumed to be linear in quality. Each high segment consumer values a unit of the product with quality q at $\theta_h q$, while each low segment consumer values at $\theta_l q$, given that $\theta_h > \theta_l > 0$. On the supply side, the marginal cost of supplying the product increases as a quadratic function of its quality q so that it is cq^2, where $c > 0$. Any fixed costs of product introductions are ignored, and there are constant returns to scale in producing multiple units of one quality. Finally, in sequential product introduction strategy, the time between successive introductions is assumed to be fixed exogenously.

The firm must decide if, how and in what order to serve the high and low market segments. He can serve only one segment, both segments simultaneously or sequentially. They initially analyze the case where the firm can commit in advance to the qualities, prices and the order in which two products will be introduced. The firm's product line design problem under sequential product introductions strategy (where it chooses quality q_h at price p_h for release in period 1, and q_l at price p_l for release in period 2) is given as follows:

$$\text{Maximize}_{q_h, q_l, p_h, p_l} \quad N_h(p_h - cq_h^2) + \delta_s N_l(p_l - cq_l^2) \tag{2–4a}$$

$$\text{subject to} \quad \delta_c(\theta_l q_l - p_l) \geq (\theta_l q_h - p_h), \tag{2–4b}$$

$$(\theta_h q_h - p_h) \geq \delta_c(\theta_h q_l - p_l), \tag{2–4c}$$

$$\theta_l q_l \geq p_l, \tag{2–4d}$$

$$\theta_h q_h \geq p_h. \tag{2–4e}$$

A consumer who purchases in the second period must wait to enjoy the product. Since most individuals prefer to consume earlier rather than later, it is assumed that each consumer equates one unit of consumer surplus in the second period to $\delta_c \in (0, 1)$ unit in the first period. So the discount factor, δ_c, will be close to 1 if consumers are very patient, while it will be close to 0 if they are very impatient. Similarly, $\delta_s \in (0, 1)$ represents the firm's discount factor on second-period profits. In this problem formulation, constraints (2–4b) and (2–4c) are the "self-selection" constraints for the two segments: since the seller cannot identify the consumer's type, he must design the product line so that each segment voluntarily chooses the product-price combination meant for it. The other two constraints are the "participation" constraints that ensure that each segment will buy the product directed to them rather than not buy anything at all.

Moorthy and Png (1992) also analyze the firm's problem when it cannot commit in advance to a product and pricing strategy. They show that if firm offers two products, then it should introduce the high-end product before the low-end product (forcing consumers that want the low-end product to wait), rather than introducing both at once to minimize cannibalization in market. Furthermore, the firm needs to pre-commit to the design of the low-end product to be introduced later in order to obtain the greatest reduction in cannibalization. This is because, without commitment, the firm can only alleviate cannibalization by the unavailability of the low-end product, while he can reduce it by differentiating the design of low-end product from that of its high-end counterpart with commitment.

Balachander and Srinivasan (1994) analyze a similar problem that addresses a single firm's selection of a two-product line with two decision variables; quality and price. In their model, the firm selects product line qualities and prices to credibly signal its competitive advantage to an uncertain potential entrant and more importantly to dissuade the potential entrant from entering the market. The incumbent enjoys a competitive advantage because it is a superior producer of quality (i.e., it can produce a given quality level at a lower cost compared to a potential entrant) and aims to use this advantage through its product line selection. They analyze the incumbent's selection of a two-product line with two decision variables; quality and price. The market consists of two segments; a high-valuation segment and a low-valuation segment. Consumers in high segment have a higher reservation price for any given level of quality than do low-valuation segment consumers. Each segment consists of one consumer, and each consumer in a segment buys one unit of a product in a period. They consider a two-period framework with pre- and post-entry periods. In the first period, the incumbent chooses the qualities and prices of the products. The entrant observes these products at the beginning of the second period, depending on which it decides whether to enter the market. Here, the entrant does not have perfect information about whether the incumbent is a superior firm or inferior firm.

In contrast to Mussa and Rosen (1978) and Moorthy (1984), they conclude that the superior firm adopts a product line with a higher quality and so a higher price for each segment to dissuade potential entrants from entering the market. The high prices signal low profit for the potential entrant because competing with a superior incumbent does not compensate for the high costs of market entry. Furthermore, in the presence of product quality modification (and when it is costly), the superior incumbent retains the high-quality product in the second period through selecting a higher quality and price for each product in the line.

In a similar two-period setting of Moorthy and Png (1992), Dhebar (1994) analyzes a profit-maximizing firm that sells a series of products of improving versions (e.g., features, functions, performance measure) to a heterogenous consumer market, and looks at the effect of product improvement on the price of current technology. Their approach differs from that of Moorthy and Png (1992) in a way so that the firm does not have the know-how necessary to introduce the high-quality product in the first period and must decide on the extent of product improvement. He looks at two cases: one in which technology is changing at a moderate pace and another in which technology is changing at a rapid pace. A given quality level is assumed to be available in the first period, and the firm intends to choose first- and second-period prices and second-period quality level to maximize the present value of its profits. On the market side, consumers attempt to maximize the present value of their consumer surplus by deciding on whether and when to purchase the product. At this point, they take into account the quality and price of the contemporary version of the product, and expected quality and price of a future version (if any).

The consumer market here is considered to be heterogenous in its valuation of quality: given a quality level q, consumers at low-end (high-end) value the product less (more). Consumers are ranked according to their valuation of the quality by the index θ: $\theta = 0$ represents the most low-end consumer, while $\theta = 1$ represents the most high-end consumer. It is further assumed that θ is uniformly and continuously distributed on the interval $[0, 1]$. The maximum willingness to pay of a consumer with index θ for a product q is given by $V(q, \theta) = f(q)g(\theta)$, where $f(q) \geq 0$ is strictly increasing in q and $g(\theta) \geq 0$ is strictly increasing in θ. Knowing that product (q_1, p_1) will be offered in the first period, and (q_2, p_2) in the second period, consumers can self-select whether and when to purchase the product. Let δ be the one-period discount factor ($\delta = 1/[1+$discount rate$]$) and it is same for all consumers, consumers with index θ will purchase the product in the first period if and only if

$$\begin{aligned} &f(q_1)g(\theta) - p_1 \geq 0, \quad \text{and} \\ &f(q_1)g(\theta) - p_1 \geq \delta[f(q_2)g(\theta) - p_2], \end{aligned} \tag{2–5}$$

and any consumer who has not purchased the product in the first period will purchase it in the second period if and only if

$$f(q_2)g(\theta) - p_2 \geq 0. \tag{2–6}$$

Their analysis shows that when rational consumers anticipate the firm's opportunistic pricing behavior, the firm's profit-maximizing pricing scheme results in no sales of one of the product versions. Consumers are given only one option to buy the product (either now or later) and upgrading the product is not possible unless an upgrade price is offered. Facing rapid improvements, prior consumers may regret their buying decision and prospective customers could delay their purchase timing. This forces the firm - who primarily uses prices to segment markets - to consider restraining the pace of innovation.

Kornish (2001) uses a similar setup to Dhebar (1994): A two-period problem of a single firm that sells sequential versions of a product in the face of rational consumers.

Each consumer decides on market participation and purchase timing to maximize his surplus. In her model, the technological improvement is considered to be exogenous and it happens between the first and second periods (in contrast to Moorthy and Png (1992), where both products are available in the first period). The profit-maximizing firm sells sequential versions of one product with zero marginal costs and uses the product replacement strategy: it sells only the latest generation in any period. She generalizes the utility function used in Dhebar (1994), disallows upgrade pricing but allows old customers to upgrade even without such pricing. In this context, she attempts to answer if it is really better for the firm to introduce as good a product as it can as fast as it can, or there is a demand-side constraint which makes a moderate pace the best choice. Looking at comparative statistics, she finds that if the firm does not segment the market in the second period, that is, if it does not offer special upgrade pricing, then an optimal pricing strategy exists even when technology is improving in the present value terms.

Prior research, such as Moorthy and Png (1992), have shown that to minimize cannibalization in a market where consumers agree on their ranking of available products but differ in their willingness to pay, a single firm offering two products should introduce the high-end product before the low-end product, rather than simultaneously. Therefore, consumers who want the low-end product are forced to wait. Padmanabhan et al. (1997) use a two-period model to analyze the implications of demand externality on sequential product introduction strategy. They assume that the firm is exogenously endowed with a certain market potential (i.e., demand externality) and that this information is not common knowledge (i.e., the firm knows the demand potential through pre-launch market research, but consumers are initially uncertain). The product market exhibits network externality, and so a customer's utility for a product increases with the number of adopters of the product. They show that it is useful in credibly conveying a firms private information about market potential to consumers in the presence of demand network externality. More recently, Bhattacharya et al. (2003) question whether the result provided by Moorthy and Png (1992) does hold in the presence of concurrent evolution of technology that may delay the introduction of a high-end product. The analysis of both Padmanabhan et al. (1997) and Bhattacharya et al. (2003) show that the reverse strategy may be optimal in the presence of network externality and in the face of technological improvement (as the option to introduce the high-end product first does not exist until technology is sufficiently advanced), respectively.

Recently, Mallik and Chhajed (2006) consider product introduction strategies of a single firm under valuation changes of the consumers and cost savings. The firm faces a market consisting of two segments with differing valuations for quality, namely high and low consumer segments. A two-period model is analyzed where a maximum of two products can be introduced in each period; one targeted to the high segment, and the other targeted for the low segment. Unlike Moorthy and Png (1992), consumers are allowed to make repeat purchases over two time periods. In addition, the model accounts for valuation change over time; that is, once a high-end product is introduced in the market, the consumers discount it over time as its value diminishes for them. For instance, a cell phone with a built-in digital camera is considered a high-end product in its first design cycle, but looses its exclusivity quickly in its next design cycle. Finally, the firm is allowed to derive cost savings due to learning effect in the second period, the magnitude of which depends on the sales volume in the first period. In this setting, they attempt to determine under which conditions the firm should follow the strategy of introducing the high-end product followed by a low-end product (or vice versa), or it should expand or consolidate its product line, and how these decisions change under valuation change for consumers.

They consider five product introduction strategies: (a) Stable Single Product Strategy, where the firm offers one product designed for one and the same consumer segments in both periods; (b) Varying Single Product Strategy, where the firm offers only one product in each period, but the product along with its target consumer segment changes from the first to the second period; (c) Expanding Product Line Strategy, where the firm begins with a single product in the first period and expands the product line to two products in the second period; (d) Consolidating Product Line Strategy, where two products are offered in the first period; and (e) Stable Product Line Strategy, where both products are offered in each period. In the proposed model, the high segment (h) values quality level q at $\theta_h q$, and the low segment values it at $\theta_l q$ (with $\theta_h > \theta_l$). The marginal cost of supplying the product is assumed to be a quadratic function of quality: cq^2, where $c > 0$. The valuation change in the second period is modeled by two parameters $0 < \psi_h \leq 1$ and $0 < \psi_l \leq 1$ such that if a high-end product is introduced in the first period, the new valuations for the high and low segment in the second period will be $\psi_h \theta_h$ and $\psi_l \theta_l$, respectively. The cost savings (or learning effect) is captured by the parameter $0 \leq \alpha < 1$, representing the maximum fractional cost savings per unit. Therefore, if both segments buy the product in the first period, $(1 - \alpha)c$ will be the cost coefficient in the second period.

The formulation of this problem is completely in line with that of Moorthy and Png (1992). The analysis of the model provides cannibalization and profitability measures that govern the optimal product introduction strategy for the firm. Moorthy and Png (1992) conclude that when there is no repeat purchase, a firm should always introduce a high-end product before a low-end product. The authors conclude that under repeat purchase, the strategy of introducing a low-end product followed by a high-end product can be optimal for the firm. In addition, they show that introduction of low-end product in both periods can never be a optimal strategy, while stable product line strategy of offering both products in each period is the dominant strategy under no valuation change.

More recently, instead of beginning with the premise that offering a product line is optimal and then just tackling the question of pricing, Anderson and Dana (2009) attempt to answer the question of whether to price discriminate is always optimally profitable and characterize the necessary conditions for price discrimination to be profitable. There are numerous examples where a firm may choose to offer a single version of a product, choose a constant price over time, or choose to serve all consumers in market with a single queue. In this line, they initially consider a single firm that chooses the prices and qualities of the products it sells - subject to an upper bound on quality - facing a market comprised of two segments; high and low valuation segments. Then, they consider a more general model in which there are a continuum of heterogenous consumers. They identify three conditions that determine when price discrimination is profitable or not; namely the monotone hazard rate, single crossing and increasing percentage differences conditions. The monotone hazard rate condition is solely based on the consumer type distribution, while the single crossing property is completely related to consumer preferences. The third condition distinguishes itself from previous two conditions as it integrates both supply side (i.e., firm costs) and demand side (i.e., consumer preferences) conditions. According to this condition, price discrimination is profitable if the percentage change in surplus (i.e., consumers' total willingness to pay, less the firm's costs) associated with a product upgrade is increasing in consumers' willingness to pay.

2.1.1.1 Commonality and product platforms in product line design

The use of commonality or component sharing in the design of differentiated products provides firms an opportunity to satisfy diverse consumer needs with less expenses due to economies of scale in procurement, production and distribution. Companies widely view component sharing as a way to have high product variety in the marketplace and low variety in operations. For example, 85% of the 250 new products introduced by Sony during the 1980s shared several common components and were only different with respect to minor feature changes or aesthetics[2] . On the other hand, the common use of particular components (e.g., car body panels) can increase similarity across products and result in “look alike” products that can in turn influence consumers’ valuation and choice of offerings. This may result in product cannibalization due to product similarity - differing from the cannibalization due to the substitution effect. The trade-off involved in component sharing thus complicates commonality or component-sharing decisions in product line design. Even though this trade-off has gained considerable visibility and research attention lately, just a few researchers prescriptively modeled the impact of component sharing on quality and how component sharing can be effectively used to satisfy market segments with differing quality needs.

Kim and Chhajed (2000) study the trade-off between the cost-savings and losses due to reduced product differentiation by means of component commonality. They explicitly consider the impacts of commonality on consumers’ valuation of products when it is used to design products in different classes. Their model incorporates the issues of commonality and similarity by extending the economic modeling framework developed by Moorthy and Png (1992). They derive conditions under which commonality helps a firm to increase revenue, and point out when the common design strategy is optimal compared to non-common product design strategy. Besides, they attempt to find out how product similarity interacts with cannibalization (due to substitution effect) and how the product design with commonality differs from the one without commonality.

They analyze a firm that serves two market segments with differing valuations of quality, namely high segment h and low segment l. Consumers’ utility is a linear function of quality so that a quality q provides a utility $\theta_h q$ to the high segment with quality valuation θ_h and a utility $\theta_l q$ to the low segment with quality valuation θ_l ($\theta_h > \theta_l$).

[2] S. Sanderson and M. Uzumeri, “Managing Product Families: The Case of the Sony Walkman,” *Research Policy*, September 1995

They assume that overall quality q is provided to consumers through a modular design q_m, representing commonality, and a custom design $q - q_m$ specific to the types of consumer. They introduce a valuation change factor, $0 \leq \beta \leq 1$, due to the product similarity if common design is used. It affects the perceived quality of products such that (a) common design used in the low-end product provides a valuation premium β_p for its buyers and the perceived quality of low end product increases to $q_l + \beta_p q_m$, and (b) the high-end product undergoes a valuation discount β_d due to commonality so that the perceived quality of high-end product reduces to $q_h - \beta_d q_m$. On the supply side, cost of providing a unit of quality increases at an increasing rate as the level of quality increases and is given by cq^2. When a common modular design is used for the design of multiple products, a cost saving of $c\eta f(q_m)$ occurs, where $0 \leq \eta < 1$ is the cost saving parameter and $f(q_m)$ is the cost saving function that is non-decreasing in q_m. Therefore, the total is given by $c(q^2 - \eta f(q_m))$.

The model for the case when the firm target a product of quality q_l at price p_l to the low segment, and one of quality q_h at price p_h to the high segment is stated as follows:

$$\text{Maximize}_{p_l,p_h,q_l,q_h,q_m} \quad N_l\left(p_l - cq_l^2 + \eta c f(q_m)\right) + N_h\left(p_h - cq_h^2 + \eta c f(q_m)\right) \tag{2–7a}$$

$$\text{subject to} \quad \theta_l(q_l + \beta_p q_m) - p_l \geq \theta_l(q_h - \beta_d q_m) - p_h, \tag{2–7b}$$

$$\theta_h(q_h - \beta_p q_m) - p_h \geq \theta_h(q_l + \beta_p q_m) - p_l, \tag{2–7c}$$

$$\theta_l(q_l + \beta_p q_m) \geq p_l, \tag{2–7d}$$

$$\theta_h(q_h - \beta_d q_m) \geq p_h, \tag{2–7e}$$

$$q_h \geq 0, q_l \geq 0, q_h \geq q_m, q_l \geq q_m, q_m \geq 0, \tag{2–7f}$$

where equations (2–7b) and (2–7c) are the self-selection constraints that are imposed to ensure that each segment will voluntarily buy the product designed for that segment, and equations (2–7d) and (2–7e) are the participation constraints to ensure that each segment gets nonnegative surplus from the purchase of the product.

Their analysis shows that component commonality is profitable only when the target segments' valuations of quality are not too different or when the lower-valuation segment is substantial, such that the premium effect is more pronounced than the discount effect. If common modules are used in both high-end and low-end products, they reduce the perceived difference in quality between the products in different classes and adversely affect the profits if there is higher expectation for the difference in quality between the classes.

Desai et al. (2001) rule out such direct valuation changes and analyze alternative product design configurations with common components by introducing a model that investigates the trade-off between revenue losses resulting from reduced product differentiation and cost savings induced through design effort. Investment in component sharing across products pays off in the form of lower manufacturing costs. On the other hand, sharing components reduces the firm's ability to charge a premium for the high-end product due to higher similarity of products. In a model similar to Moorthy (1984), they consider that each product consists of two components, each available in a basic and premium version, and one of the components can potentially be common between the two products or go as a distinct component in each of the two products. For each component, the firm further has the option to invest in design effort to reduce manufacturing costs. In essence, they analyze three design configurations; unique, premium-common, and basic-common, and derive conditions for the overall profitability of commonality, and find out an index as well to rank order components in terms of their attractiveness for commonality.

The proposed model is analyzed in two-stages. In the first stage, the component qualities are assumed to be predetermined, and the objective is to determine whether to make a component common across products, and whether to make the low-quality or the high-quality component common. In the second stage, the component qualities are determined as well. For two products, the analysis shows that premium-component sharing increases revenues from the low-end segment, compared to no sharing. The average quality of the products offered to the two segment increases, too. However, sharing premium-component may not increase overall revenues as it decreases the perceived differentiation between the two products. They also find that commonality always leads to cost reductions and a less attractive product line with decreased revenues.

As in Desai et al. (2001), Heese and Swaminathan (2006) do not incorporate direct valuation changes that could stem from a common component. They develop a stylized model of a single firm that designs a product line with two products offered to a market with two segments that have different valuations of quality. The two products consist of components that can be common or unique to both products. The firm determines the component quality levels, and whether to use common or different components for the two products. For each component, the manufacturer can reduce the cost of production by exerting a certain amount of effort. While their model and research focus is similar to Desai et al. (2001), their modeling approach fundamentally differs in how the relation between effort and production costs is modeled. Desai et al. (2001) use an additive model and thereby implicitly assume that the marginal cost of quality is independent of effort. On the other hand, Heese and Swaminathan (2006) use a more general function (includes both the general additive model and general multiplicative model) that explicitly captures potential interactions. By explicitly considering potential interdependencies between cost reduction effort and quality decisions, they question the paradigm that component commonality can substantially lower the costs of proliferated product lines, but at the cost of reducing product differentiation and lower revenues. Furthermore, they characterize environments where the optimal product line involving component commonality features products of higher quality and yields higher revenues, and identify which components are the best candidates for commonality.

The findings of this study contrast strongly with the results in Desai et al. (2001). Contrary to the conventional paradigm that the loss of product differentiation under commonality always leads to less attractive product lines, it is shown that common components might indeed lead to a more attractive product line and yield higher revenues compared to a product line of different variants. The components that are attributed to a higher importance by consumers relative to their production cost are preferred for commonality. They also show that disregarding interdependencies between quality, effort decisions and production cost can lead manufacturers to offer product lines with excessive differentiation and average quality far below the optimal level.

In their quest to manage the increasing costs attributed to offering greater product varieties, firms in many industries are also investing in platform-based product development that enhances component sharing and so leverages investments in product design. Robertson and Ulrich (1998) define a product platform broadly as a collection of intellectual and material assets (i.e., components, processes, knowledge, and people and relationships) that are shared across a set of products. A product platform poses several opportunities for the firms: (a) it helps to tailor the products to the specific needs of different market segments or consumers because it reduces the additional cost of addressing those needs, (b) it reduces fixed cost of product development because machinery, equipment and production time can be shared across higher volumes of production, (c) the lower investment on each product developed from a platform implies decreased risk for each new product, (d) it allows firms to achieve economies of scale because they can produce larger volumes of common parts, and (e) it helps firms reduce product development time, since parts and/or processes developed for one product type do not have to be developed and tested for the others. Meyer and Lehnerd (1997) describe platform-based product development strategy as a way to map platforms onto differing market segments. At this point, the firms developing differentiated products based on a platform must meet the needs of diverse market segments while sharing parts and production steps across the products. The fixed costs of investment in developing platforms should also be accounted by the firms.

In one of the few attempts to weigh costs against benefits in deciding on platform strategy, Krishnan and Gupta (2001) develop a stylized model to derive insights about the appropriateness and impact of platforms on product line design decisions. They claim that platform strategy may strongly impact the design of products offered in a market with diverse consumers, as well as the order of product introductions when firms and consumers are impatient. To address these issues, they initially illustrate the costs and benefits of platforms using an industrial example, and then present an application-driven mathematical model. Their model incorporates over-design costs associated with using a standard platform over products with differing performance requirements, and integration benefits of platforms (i.e., cost-efficient designs stemming from the effort spent in designing the platform). They consider a profit-maximizing firm that develops a technology-based product in the face of two consumer segments - high and low segments- differing in their willingness to pay for any given quality level. Platform-based product design does appear to be profitable as the integration benefits from platforms increase and over-design costs of platforms decrease. On the other hand, platforms turn out to be not appropriate in the presence of too low/high market diversity or significant economies of scale. They tend to increase the optimal quality level of the high-end product (owing to the integration benefits without any over-design costs) and over-design of low-end products. More importantly, a platform increases the separation among products and offers a multitude of product introduction strategies.

Treatment of platforms in the extant literature is mostly at a conceptual level and focuses more on the benefits than the costs of the platforms. This trade-off is taken into account by Krishnan and Gupta (2001), yet the primary focus of their proposed model is on managerial insights rather than implementation. Apparently there are important issues (e.g., competition, demand- and supply-side uncertainties) that have to be factored into decision making about a platform-based product family, and so the critical link between platforms and product line design merits further research attention.

2.1.1.2 Product line design in distribution channels

In determining a product line design, a manufacturer usually does not have the control over the ultimate targeting of the products within the line to the different consumer segments in the marketplace. In many industries, they depend on retail stores to sell their products to end consumers, and so product line design decision is indeed made by a retail store such that it evaluates the products supplied by the manufacturer and their intermediate prices, and then decides on which products to display, as well as the target consumer segments. At this point, the manufacturer should account for the retailer's strategy in a way so that the retailer is willing to carry all the products in the line and target each one to the consumer segment designated by the manufacturer. For instance, the manufacturer can narrow down the number of products available to the retailer to limit retailer's discretion, or alternatively it can increase the differentiation among the products offered to the retailer.

Related to this point, Villas-Boas (1998) studies the product line design problem in a two-stage distribution channel (an upstream manufacturer and a downstream retailer), and attempts to find out the main issues a manufacturer selling through a distribution channel has to take into account when designing a product line. In his model, the manufacturer decides how many products to have in the line as well as the quality level of each product. Each product can be targeted at a different market segment, or not. Besides, the manufacturer decides how many market segments to try to target and the prices to charge the retailer for each product type. Given the product line being offered by the manufacturer, the retailer decides which products to carry, the market segments that are going to be targeted, which product to target to each segment, and the prices being charged the consumers for each product. In this paper, the consumer market is composed of two market segments with varying willingness to pay for quality.

It is shown that the best strategy for the manufacturer, if possible, is to increase the differences among the different products being offered (in comparison to the direct selling/coordinated channel case). If the manufacturer is not able to increase these differences, then it selects to price the product line such that low-end consumer segment ends up not being served and it concentrates on the high-end segment.

Netessine and Taylor (2007) analyze the impact of production technology on the product line design for a firm by combining the product line design problem proposed by Moorthy (1984) with the classical economic order quantity (EOQ) model. The firm segments the market on quality attributes and offers products that are partial substitutes. Consumers can self-select from the product line, and so product cannibalization is an issue. In addition, the firm sets a production schedule in order to balance the fixed cost of production setups with accumulation of inventories in the presence of economies of scale. Secondly, they analyze the impact of information in the presence of production technology by comparing two settings: full information case and asymmetric information case.

On the demand side, consumers belong to one of the two segments. Consumers of type $t = h, l$ have valuation $\theta_t q$ for the product, where q denotes product quality and $\theta_h > \theta_l$. Each consumer's utility from the product is $\theta_t q - p$, where p is the product's price. Consumers of type t exogenously arrive at a deterministic rate of λ_t per unit time, and each consumer decides which product to purchase (if any) based on his/her derived utility upon arrival. On the supply side, the production costs are modeled explicitly using the EOQ model. The per-unit production cost of a product is a quadratic function of its quality q: cq^2, where $c > 0$. Each manufactured product is instantly produced to stock in batches of size Q, and the firm incurs fixed setup cost $F \geq 0$ for each batch. Each unit of inventory incurs a holding cost that is proportional to the product's cost icq^2; $i \geq 0$. Here, $\{c, i, F\}$ characterize the production technology. When the firm sells one product to each segment, the firm's product line design and production scheduling problem under the asymmetric information case is as follows:

$$\text{Maximize}_{q_l, q_h, Q_l, Q_h, p_l, p_h} \quad \Pi = \sum_{t=h,l} \left[(p_t - cq_t^2)\lambda_t - \frac{\lambda_t F}{Q_t} - \frac{icq_t^2 Q_t}{2} \right] \tag{2–8a}$$

$$\text{subject to} \quad \theta_l q_l - p_l \geq 0 \tag{2–8b}$$

$$\theta_h q_h - p_h \geq 0 \tag{2–8c}$$

$$\theta_l q_l - p_l \geq \theta_l q_h - p_h \tag{2–8d}$$

$$\theta_h q_h - p_h \geq \theta_h q_l - p_l \tag{2–8e}$$

The last two constraints are dropped under the full information case, since the firm knows the preferences of individual consumers, can segment the consumers perfectly, and the cannibalization problem does not arise.

It is found that more expensive production technology (in the sense of higher relevant cost parameters) can lead to a product line of higher quality products at lower prices. When production costs are large enough, the firm capitalizes on offering fewer products either by offering a composite product targeted to both segments (when segments are close to each other), or by serving only the high-quality segment with a high-quality product (when segments are far apart). It is also demonstrated that the cannibalization may distort product quality upward or the number of products upward in the presence of production technology, which is contrary to result of standard model omitting the demand side or supply side of the equation.

Xu (2009) extends the work of Villas-Boas (1998) by using a general demand function and focusing on the joint price-quality decisions of a single product in two distribution channel structures: the manufacturer sells the product directly to consumers or the manufacturer sells the product through a retailer. In this model, the manufacturer jointly determines the wholesale price and quality of the product, and then the retailer determines the retail price. The utility a consumer derives from the purchase of a product is represented by the function $U(p, q) = \varpi(q) - \gamma(q)p + \epsilon$, where p represents the product price, q the product quality, $\varpi(q)$ the observable utility value of the product, $\gamma(q)$ the price sensitivity, and ϵ the consumer heterogeneity. The analysis shows that if the marginal revenue function is: (a) strictly concave, then the manufacturer chooses product quality level that is lower than if selling the product directly to customers; (b) affine, then the manufacturer's optimal product quality decision does not depend on the type of distribution channel; and (c) strictly convex, then the manufacturer chooses a higher product quality level than if selling the product directly to customers.

Tang and Yin (2010) consider a firm that has to select vertically differentiated products to sell as well as the selling price and production quantity of each selected product. The firm has two substitutable products in the consideration set, where product 2 has a higher quality and reservation price than that of product 1. To capture the fact that product 2 is preferred to product 1 in a homogenous market, they assume that $V_2 = \varphi V_1$, where V_i (distributed uniformly over $[0, 1]$) is the reservation price of each consumer for product i ($i = 1, 2$) and $\varphi > 1$ is a constant. Given the market size N and the market share of product i, $MS_i = Prob\{V_i \geq p_i\}$, the demand for product i is $MS_i \times N$. By incorporating the cannibalization effect that depends on the selling price of each product (e.g., product 1 of lower quality can cannibalize the sales of product 2 if its selling price is sufficiently low), they evaluate the profit function associated with three different product line designs: sell both products or only one of the 2 products. Additionally, the model is extended to incorporate two additional issues: production capacity and price competition. They find that the unit production costs and production capacity can be partitioned into different regions, each of which has a corresponding optimal product line selection.

Hua et al. (2011) investigates the product design problem in a two-stage distribution channel that consists of an upstream manufacturer and a downstream retailer. In a distribution channel, the ultimate targeting of products in the line to different market segments is controlled by the retailer, and so interactions between the manufacturer and the retailer, and between the retailer and consumers are critical in choosing the best product design strategy in a distribution channel. Consumers are classified into two market segments (i.e., high segment h and low segment l) according to their valuations of quality. In each segment, consumers make their buying decisions so as to maximize their utility. For each of the two potential market segments, the manufacturer needs to decide if it is beneficial to design a product with appropriate quality level to meet the demand of consumers in each market segment. It has four possible product design options: (a) design two products for the corresponding two markets, (b) design just one product catering to only one of the two market segments, and not serving the other segment, or (c) design no product. In this framework, they initially analyze the optimal product design strategy when the retailer and the manufacturer do not cooperate, and secondly apply the revenue-sharing contract to the product design problem to coordinate the distribution channel.

On the market side, h segment consumers have a higher marginal valuation θ_h per unit quality than that of l segment consumers θ_l, with $\theta_h \geq \theta_l > 0$. Given that the retailer sells the product j ($j = h, l$) at price p_j, the market demand in segment i, D_i ($i = h, l$) is described as a linear function of p_j so that $D_i = N_i - \delta_i p_j$, where $N_i > 0, 0 < \delta_h < \delta_l, N_i/\delta_i \geq p_j \geq 0$ for $i = j = h, l$. The utility that a consumer in market segment i derives from the product (q_j, p_j), U_{ij}, is given by $U_{ij} = \theta_i q_j - p_j$. On the supply side, manufacturing cost of a product with quality q_j is assumed to be a quadratic function of quality so that $C(q_j) = c_j q_j^2$, where $c_j > 0$. When the manufacturer sells product j to the retailer at price w_j, the profits of the manufacturer (π_m) and the retailer (π_r) from two products (one targeted to h segment and other targeted to l segment) under non-cooperative scenario are as follows:

$$\begin{aligned}\pi_m &= (w_h - c_h q_h^2)(N_h - \delta_h p_h) + (w_l - c_l q_l^2)(N_l - \delta_l p_l)\\ \pi_r &= (p_h - c_h q_h^2)(N_h - \delta_h p_h) + (p_l - c_l q_l^2)(N_l - \delta_l p_l)\end{aligned} \tag{2–9}$$

Regarding the coordination scenario, the authors introduce the notion of revenue-sharing contract, where the manufacturer charges low wholesale price to the retailer and shares a fraction $1-\mu$ ($0 \leq \mu \leq 1$) of revenue generated by the retailer. In this setting, the profit functions of the manufacturer and retailer gets the following form:

$$\begin{aligned}\overline{\pi}_m &= ((1-\mu)p_h + w_h - c_h q_h^2)(N_h - \delta_h p_h) + ((1-\mu)p_l + w_l - c_l q_l^2)(N_l - \delta_l p_l) \\ \overline{\pi}_r &= (\mu p_h - c_h q_h^2)(N_h - \delta_h p_h) + (\mu p_l - c_l q_l^2)(N_l - \delta_l p_l)\end{aligned} \tag{2–10}$$

The analysis reveals out that the revenue-sharing contract can perfectly coordinate the distribution channel in the product line design problem through reducing the difference of consumers' utility in different market segments, and so the performance of the supply chain can be significantly improved. Besides, the application of the revenue-sharing contract to the product design problem results in a similar structure of the scenario of non-coordination.

2.1.2 Product Design with Multiple Attributes

In the models highlighted so far, a product is characterized by a single quality-type attribute, and consumers' willingness to pay (part worth) is measured with this single attribute. A single-attribute analysis is often useful in cases in which there exists a major attribute along which product differentiation mostly occurs, or where consumers exhibit similar preferences for different attributes so that the attributes can be aggregated. However, in many cases in practice, products are usually designated with multiple attributes for which customers may exhibit heterogeneous preferences. It has not been clear whether the insights from the single-attribute analysis are still valid in such situations. In order to fill this gap in literature, certain papers (see, for example, Kohli and Sukumar (1990), Dobson and Kalish (1993), Nair et al. (1995), Raman and Chhajed (1995), among others) have explicitly considered multiple attributes in product line design problems. However, in these studies, the problems are formulated as a discrete optimization model and the focus is on finding the optimal/heuristic solutions, rather than offering managerial insights.

An interesting study in this category is provided by Chen (2001) who develops a utility model with two quality-type attributes on the basis of the self-selection models introduced by Moorthy (1984) and Moorthy and Png (1992). He analyzes a firm's strategic decisions and policy issues regarding the design of a product line in a vertically differentiated market. The firm intends to supply all its consumers in the market with either a single product type or two product types. It should adopt a profitable product strategy that specifies the number of product types to be developed, as well as their qualities and prices before any sales take place. As mentioned above, a product is characterized by two quality-type attributes, namely traditional and environmental attributes, over which consumers can express quantifiable preferences. Improvements in traditional and environmental qualities (i.e., q_t and q_e) are often coupled and traded off in design. For instance, safety rating and fuel economy of a vehicle usually conflict with each other. The competing nature of these two qualities is incorporated into the model with constraint $q_t + q_e = 1$. This distinguishes his paper from those of Moorthy (1984) and Moorthy and Png (1992) who do not take into account the interactions of conflicting product qualities and attributes. On the demand side, the target consumer market is divided into two homogenous segments: ordinary segment and green segment. Ordinary segment consumers value a unit of a product (q_t, q_e) at $\theta_t q_t$, where θ_t is the marginal valuation on the traditional quality. On the other hand, consumers in green segment derive additional utility from environmental attribute and so value a unit of a product (q_t, q_e) at $\theta_t q_t + \theta_e q_e$, where θ_e is the marginal valuation on the environmental quality. On the supply side, the cost of supplying a product is assumed to be a quadratic function of its two qualities so that it is $c_t q_t^2 + c_e q_e^2$, where $c_t, c_e > 0$. He also introduces a fixed cost F for R&D and other relevant expenses for developing any product type.

He focuses on two product introduction strategies: mass marketing and market segmentation with self-selection. Mass marketing strategy is characterized by the introduction of a single product that serves both segments, while the strategy in market segmentation is to introduce a green product targeted to green segment, along with a traditional product targeted to ordinary segment. Under mass marketing strategy, it turns out that the firm adopts a wait-and-see policy and ignore green consumers' preferences for environmentally friendly products. Under market segmentation strategy, the firm offers a green product to the green segment with the segment's preferred qualities. Furthermore, he shows that number of green consumers and their valuation of environmental quality drives green product development, while number of ordinary consumers and fixed cost identify obstacles. Regarding the total environmental quality supplied in all products, comparison of two strategies indicate that overall environmental quality is not improved as a result of green product development. He also analyzes the effects of environmental standards on the environmental consequences of green product development, and shows that stricter environmental standards do not necessarily improve overall environmental quality.

Likewise, Kim and Chhajed (2002) extend the works of Mussa and Rosen (1978) and Moorthy (1984) that consider a single quality-type attribute to a model with a bundle of quality attributes, and study the development of a product line consisting of vertically differentiated products to serve a market with two consumer segments. Consumers in a segment are homogenous in their part worth for attributes. The products are characterized by a bundle of K quality-type attributes, for which consumers may exhibit different order of preference. Designing a product involves setting the level of each attribute; the level of attribute k offered in product j is denoted by q_{jk}, where $j = 1, 2$ and $k = 1, \ldots, K$. On the demand side, a consumer's overall utility from a product is assumed to be the sum of the individual part worths from different attributes. Then, the utility to segment i from product j is given as $\sum_k \theta_{ik} q_{jk}$, where θ_{ik} is the segment i's part worth for attribute k. On the supply side, they assume that the per-unit manufacturing cost of a product is a quadratic function of the level of attributes in the product, and is given as $\sum_k c_k q_{jk}^2$. The products are considered to be differentiated vertically if one product is better than the other with respect to all attributes.

In their article, the multi-attribute model with two consumer segments is written as follows:

$$\text{Maximize}_{p_1, p_2, q_{1k}, q_{2k}} \quad N_1 \left(p_1 - \sum_{k=1}^{K} c_k q_{1k}^2 \right) + N_2 \left(p_2 - \sum_{k=1}^{K} c_k q_{2k}^2 \right) \tag{2–11a}$$

$$\text{subject to} \quad \sum_k \theta_{1k} q_{1k} - p_1 \geq \theta_{1k} q_{2k} - p_2 \tag{2–11b}$$

$$\sum_k \theta_{2k} q_{2k} - p_2 \geq \theta_{2k} q_{1k} - p_1 \tag{2–11c}$$

$$\theta_{1k} q_{1k} \geq p_1 \tag{2–11d}$$

$$\theta_{2k} q_{2k} - p_2 \tag{2–11e}$$

$$q_{1k} \geq 0, q_{2k} \geq 0, \forall k \tag{2–11f}$$

The objective function is the firm's profit, where N_i represents the size of segment i and p_j denotes the price of product j ($j = 1, 2,$) offered to segment i. Equations (2–11b) and (2–11c) are self-selection constraints, imposed to ensure that consumers purchase the product aimed at their own segment. Equations (2–11d) and (2–11e) are participation constraints that ensure that each segment gets nonnegative surplus from purchasing the product. The authors concentrate on participation constraints to obtain a price-quality schedule, and analyze three cases; Case 1 where both segments get zero surplus, Case 2 where the first segment gets positive surplus but the second segment gets zero surplus, and Case 3 where the second segment gets positive surplus but the first segment gets zero surplus.

The analysis of the model indicates that the results from a one-dimensional model extend for the most part when there is a strict vertical differentiation. A single-product offering strategy is never optimal when the orders of preference on product attributes between customers are different. Furthermore, when a bundle of attributes with non-crossing preference function is considered, supplying socially efficient products is implementable, and this is possible because the firm can make use of the multidimensional aspect of consumer preference to avoid cannibalization within a product line. These results, however, are limited in that only two consumer segments are considered, and so it has not been clear whether the results are still implementable when more than two segments are taken into account, and if implementable, under what conditions. To address this issue, Chhajed and Kim (2004) consider a product line design problem with multiple attributes for a firm who serves multiple consumer segments, and show that the results do hold only if the part-worth between segments is sufficiently separated.

In line with the multi-attribute models of Chen (2001) and Kim and Chhajed (2002), Krishnan and Zhu (2006) consider a profit-maximizing firm facing a heterogenous market of vertically differentiated consumers but focus on the design of development-intensive products (DIPs). The fixed costs of development of DIPs far outweigh their unit-variable costs, and the authors attempt to analyze whether the managerial insights from the traditional approach to product-line design developed for unit-variable cost-intensive products carry over to DIPs. They consider a market comprised of two segments, h and l, where consumers differ in their willingness to pay (WTP) for quality. To cover two market segments, the firm can either position and price a dedicated product for each segment, in which consumers self-select from these two products, or offer a single product.

A product is characterized by two quality-type attributes, indexed with subscripts 1 and 2. On the supply side, the coupling between the quality dimensions is modeled by a supermodular cost function: the cost to provide product A with quality $q_A(q_{A1}, q_{A2})$ is $C(q_{A1}, q_{A2}) = c_1 q_{A1}^2 + c_2 q_{A2}^2 + 2d q_{A1} q_{A2}$, where d ($0 \leq d < \sqrt{c_1 c_2}$) is the degree of coupling of the cost function. The utility derived by consumers in each segment is assumed to be a linear function of quality. Additionally, saturation quality (i.e., quality beyond which consumers' WTP tapers off) and reservation quality (i.e., quality beyond which consumers would not even consider buying the product) are introduced as constraints. The cumulative WTP of consumer type t for product A with quality $q_A(q_{A1}, q_{A2})$ is denoted by $U_t(q_{A1}, q_{A2})$, and is a function of consumer t's reservation qualities in two dimensions (q_{t1}^R and q_{t2}^R), saturation qualities in two dimensions (q_{t1}^S and q_{t2}^S), and marginal WTP for quality in two dimensions (θ_{t1} and θ_{t2}), as follows:

$$U_t(q_{A1}, q_{A2}) = \begin{cases} 0 & \text{if } \exists q_{Ai} < q_{Ai}^R, i = 1, 2, \\ \theta_{t1}(q_{A1-q_{t1}^R}) + \theta_{t2}(q_{A2} - q_{t2}^R) & \text{if } q_{Ai} \in [q_{Ai}^R, q_{Ai}^S], i = 1, 2, \\ \theta_{ti} q_{ti}^S + \theta_{tj}(q_{Aj} - q_{tj}^S) & \text{if } q_{Ai} \in (q_{Ai}^S, \infty), q_{Aj} \in [q_{Aj}^R, q_{Aj}^S], i, j \in \{1, 2\}, \\ \theta_{t1} q_{t1}^S + \theta_{t2} q_{t2}^S & \text{if } q_{Ai} \in (q_{Ai}^S, \infty), i = 1, 2. \end{cases}$$

The analysis indicates that the traditional approach to product line design problem developed for unit-variable cost-intensive products do not directly carry over to DIPs when quality degradation and value subtraction are taken into account. When the quality dimensions are independent; (a) if the difference between the WTPs of the two consumer segments for product quality is high, the firm would be better off designing a subsumed product line, with the low-end product being designed with merely the reservation quality along the first quality dimension, and (b) if the differential WTP is low along both quality dimensions, it would be optimal for the firm to offer a standard product common to both segments. When the quality dimensions are conflicting; (a) if consumer's differential WTP for quality in the first dimension is low, then the firm offers an overlapped product line, and (b) if the differential is low, then it would be optimal to design a standard multi-segment product. Finally, they show that the firm has to identify additional quality dimensions to successfully address a low-end market with lower WTP such as identifying a product's usability that the low-end consumer segment cares about.

Recently, Wu (2010) studies a firm that designs and produces a single product with two quality dimensions, design quality and conformance quality, to serve end consumers with diverse willingness to pay. In order to satisfy consumers, quality has to be high on both dimensions. By integrating these two quality dimensions, this paper strives to investigate the interrelationships between design quality, conformance quality, price and market demand when overall profit is maximized. The proposed model consists of two main components: cost components that are jointly determined by design quality and conformance quality, and the revenue component that is decided by the price of the product and consumer demand. As in Mussa and Rosen (1978) and Moorthy (1984), a utility-based consumer choice model is used that assumes that the consumers will purchase the product only if it offers non-negative consumer surplus. It is shown that the optimal design quality, conformance quality and price decisions are positively interrelated. When optimal conformance quality decreases (increases), the optimal design quality decreases (increases) in order to maximize the overall profits, or vice versa. Besides, when design quality or conformance quality declines, the optimal selling price of the product also decreases.

2.2 Product Line Design in Both Vertically and Horizontally Differentiated Markets

The theory of product differentiation begins with the horizontal differentiation model of Hotelling (1929). In his model, consumer utility decreases with the price and the distance between the ideal feature desired by the consumer and the product feature offered. The purpose here is to optimally position a product or multiple products in multi-attribute space where each consumer has an ideal point and chooses the product with the smallest Euclidean distance from this point. The research papers highlighted so far do not say much about horizontal differentiation as they focus on market structure models with only vertical differentiation in consumer preferences. On the other hand, Cremer and Thisse (1991) show that there exists a relationship between these two families of product differentiation: the class of Hotelling-type models of horizontal differentiation, and models of vertical differentiation. Specifically, they find that the Hotelling type-model is a special case of a vertical product differentiation model. It is worthy to note that there are certain research papers in product line design literature that have combined both types of differentiation.

Desai (2001) addresses the question of whether cannibalization affects a firm's price and quality decisions when consumer market is characterized by both quality (vertical) and taste (horizontal) differentiation. The market here consists of two consumer segments, a high-valuation segment and a low-valuation segment, that differ in their willingness to pay for any given quality level, and taste differences among consumers in each segment are represented by a linear market as in Hotelling (1929). The taste differences refer to the product attributes for which all consumers are not in agreement. The ideal product preference of each consumer is represented by his location on the line, and the strength of taste preferences is taken into account by the "transportation cost". The firm has two options: leaving out some consumers in both markets (i.e., incomplete market coverage), and covering both markets completely (i.e., full coverage of both market segments).

The analysis shows that the standard self-selection results derived by Moorthy (1984) do hold when both segments are fully covered. However, under the incomplete market coverage case, the firm's price and quality choices are not necessarily determined by the cannibalization problem. The firm is better off providing each segment with its preferred quality depending on two factors; (a) the trade-off between quality and taste preferences in consumers' utility function, and (b) the differences in transportation costs and quality valuations of two segments.

Weber (2008) develops a two-stage product line design model for a profit maximizing firm that chooses a two-product portfolio sequentially, when products can differ with respect to both vertical and horizontal attributes. In the first stage, the firm positions its high-quality "flagship" product in a market with an imperfectly known distribution of tastes and reservation prices. In the second stage, the uncertainty over the consumer characteristics is resolved and the firm has the option of extending its product line with a "versioned" product by differentiating the flagship product using pure horizontal differentiation, quality degrading, or both. That means the flagship product creates an option value to the firm of delaying product differentiation to reduce its commitment to a particular product portfolio. In this model, all consumers are initially endowed with a budget and personal taste, and each consumer of a certain type has utility that is a function of price, product quality and distance of the horizontal product attribute from one's own taste. Each product offerings targets a segment of the consumer market, and consumers can self-select by choosing the product that maximizes their respective utilities. On the supply side, the marginal cost of the products is assumed to be negligible and the cost of creating the flagship product is assumed to be a linear function of quality.

The analysis indicates that even when a firm is able to extend its product line in the second period by differentiating the horizontal and vertical attributes of a high-end product, it is not optimal to differentiate with respect to both at the same time. Extending the product line through horizontal differentiation is optimal for high costs of quality (development costs); otherwise pure vertical differentiation is superior. On the other hand, for unexpectedly high realizations of demand, the firm is better off differentiating its high-end product horizontally. For low demand realizations, vertical differentiation turns out to be superior, in which case a product of degraded quality is added to the portfolio.

In like vein, Lacourbe et al. (2009) studies product line design problem for a profit-maximizing firm in a market space with two dimensions. The two dimensions reflect consumer preferences about the product attributes: consumers are vertically heterogeneous in their valuation of product performance, while they exhibit horizontal differentiation for their ideal feature taste. The firm incurs a fixed design cost and per-unit variable manufacturing cost, both of which are quadratic functions of the quality level and independent of the feature. The authors intent to study the optimal product portfolio composition addressing endogenously formed consumer segments, and to determine the number of products to be introduced, as well as the price, quality level, and feature design for each.

A product's design attributes are represented by two distinct dimensions: the performance quality q (vertical dimension), and the design feature f (horizontal dimension). On the demand side, each consumer is characterized by his incremental value $\theta \in [0, 1]$ for an additional unit of performance quality, and has an ideal feature $\tau \in [0, 1]$ and suffers a quadratic utility loss $(\tau - f)^2$ when the product deviates from the ideal feature. In this line, the consumer market space is denoted by the set $M = \{(\tau, \theta) : \tau \in [0, 1], \theta \in [0, 1]\}$. The consumer with preference τ and valuation θ derives a utility $U(p, q, f; \tau, \theta) = \theta q - e(\tau - f)^2 - p$ from purchasing the product (p, q, f). On the supply side, designing a product of quality q and producing Q units of it costs $C(Q, f) = Qc_1q^2 + c_2q^2$, meaning that feature design is cost neutral. Therefore, the objective function of the profit-maximizing firm is written as follows:

$$\text{Maximize} \quad \pi(n, \{f_j, p_j, q_j\}, j = 1, \ldots, n) \tag{2–12a}$$

$$= Max \sum_{j=1,\ldots,n} \left(\int_{(\tau,\theta)\in\Omega(p_j,f_j,q_j)} \int (p_j - c_1 q_j^2) m(\tau, \theta) d\tau d\theta - c_2 q_i^2 \right), \tag{2–12b}$$

where n is the number of products, (f_j, p_j, q_j) characterizes product j, $m(\tau, \theta)$ is the density over the market space M function, and $\Omega(p_j, f_j, q_j)$ is the subset of all consumers (τ, θ) that derive the highest non-negative utility from product j.

The key results of this research paper are summarized as follows: (a) Higher variable costs is a driver of vertical differentiation. Products with low variable costs relative to design costs have a portfolio that exhibits only horizontal differentiation; (b) Horizontal differentiation is the main profit lever, and vertical differentiation has only a limited potential to increase profitability; and (c) The low-quality product line should have more products, and market coverage increases when the willingness to pay for performance increases.

In summary, prior work centers around the key issues in managing product variety both from the firm's perspective and the individual consumer's perspective. In general, managing product development requires decision making at different organizational levels and over different time horizons before and after product launch. These works have focused on the following decisions: What are the firm's target markets? What portfolio of product opportunities will be offered? What is the timing of the development of new products? What components will be shared across products? How should a firm design its product line to balance the revenue and cost impact of its product line design decisions? In essence, the set of questions in these articles attempt to answer how a firm can pursue the right markets and products from a strategic standpoint. While determining the number and identity of individual products, the firm finds itself in the face of cannibalization. When products are introduced simultaneously, low-end products can cannibalize the sales of the high-end products. In case of sequential introduction, an interesting trade-off associated with timing decision is seen between cannibalization and faster accrual of profit.

The models developed deal with vertically differentiated products that can be ordered according to their quality-type attributes so that a higher quality product is more desirable than a lower quality product. Since all consumers have the same preference ranking for the products in vertical differentiation, something other than different preferences is required to provide markets for different qualities. The other dimension that is commonly used in these papers turns out to be the price. For any given selling price, the proposed models in these articles use constant-utility attraction models, in which each consumer derives a utility from purchasing a product that depends on marketing and operations factors such as product attributes (price and quality). The incentive for a firm to provide variety in its product line occurs when revenue can be increased by additional products because heterogenous preferences of consumers can lead them into new segments of the market or because of any economies of scope. The profitability of increased variety in product line, however, can diminish due to the economies of scale in the production of each variant. In general, a firm cannot capture all the potential consumer surplus existent in the market without perfect price discrimination and hence, the revenue gain understates the social gain. Therefore, while the outcome in these studies depends very heavily on the way in which the demands for products of different quality are distributed over the consumer market and on the cost of incorporating higher quality into a product, the degree of economies of scale in the production of each variant also plays an important part in the degree of variety.

CHAPTER 3
GREEN PRODUCT STRATEGIES

3.1 Three Broad Strategies for Green Products

Traditionally, the link between product design and the environment has not been established. Product manufacturers/designers have failed to fully consider the risks posed by their products. They tended to narrowly look only at factors such as performance and short-term costs when designing their products, often with little/no regard for the environmental and public health hazards posed by them. They focus on firm level costs rather than environmental benefits. Recently, this approach has been re-evaluated in response to greening pressures. Environmental concerns now drive new product design and innovation. At Clorox®, CEO Don Knauss has recently identified sustainability as one of three core consumer trends with which he wants to align Clorox® products[1] . Indeed, the quest for green products is now forcing companies to change the way they think about their products, manufacturing technologies/processes and business models. The most common way that product manufacturers are attacking environmental issues in their operations is by means of framing product design and innovation as a materials problem. For many of them, what matters is no longer how much material is used, but rather what material is used in their products and/or what materials are used to run their manufacturing processes. Do they put toxic chemicals into the environment? Are they recyclable? Do they emit air pollutants? Wider concerns such as the hazardous impacts on the environment and health have finally entered into the equation at many companies, and product design turns out to be the key decision point as that is where critical decisions on materials are made.

[1] http://articles.chicagotribune.com/2012-05-31/lifestyle/sns-rt-us-clorox-healthcarebre84u1dm-20120531_1_clorox-knauss-bleach-business, accessed October 4, 2012.

In essence, companies have started to realize that environmental responsibility is critical, and at the same time that it can bring with it exciting opportunities for them to help grow their sales and better compete within the rules of a more sustainable future. They have begun to see green product development as a necessity and the question they need to answer nowadays is "What is the better strategy: accentuating latent green attributes in their current products and/or making small "green" enhancements to their existing "non-green" products; launching new products that are unabashedly green; or buying someone else's green brand?" These strategies, ideally considered as part of a holistic effort to manage a company's product portfolio rather than incorporated in isolation, can inspire profitable greener products that address the new rules of balancing consumers' needs with environmental considerations. In this greening process, the path to offering greener products can be a steep climb because using responsible manufacturing practices, for instance, may demand new equipment and processes that may involve heavy investments and high risks. In 2003, to offset their plant's electricity use through solar power, Kettle Foods Inc. had more than 600 solar panels installed atop their manufacturing plant, representing one of the largest arrays in the Pacific Northwest[2] . On the other hand, this path may turn out to be as simple as just using smaller caps on plastic water bottles as is done by Zephyrhills Water Company, whose new smaller Eco-Slim® caps contain an average of 20% less plastic than their original caps[3] .

In this research, the green product strategies introduced above are referred to as: (1) Greening Up; (2) Greening Out; and (3) Greening Over. As it will be seen in the following sections, there are unique operational and executional challenges

[2] http://www.kettlebrand.com/about_us/sustainability, accessed September 12, 2012.

[3] http://www.zephyrhillswater.com, accessed September 23, 2012.

inherent in each green product strategy and each strategy choice requires very different business conditions, technical competencies, resources and potential partnerships. Such complexities make it difficult for company managers to choose and implement a profitable green product strategy, and a review of these strategies underscoring the underlying principles and rationale behind each one should make the choices and trade-offs clearer.

3.1.1 Greening Up Strategy

For the small to medium companies that are looking to sell green products, the most straightforward way is to start with their current portfolio of products and focus on greening up what they already do well - or accentuating the positive of their greener products. After examining what they are already selling through a green lens, many companies discover that some of their existing offerings already have leveragable environmental attributes that can be built upon. Heinz Vinegar has done just this, emphasizing to environmentally conscious customers that their distilled white vinegar with all natural ingredients (e.g., sun-ripened grain and crystal clear water) is a great helper around the home for cleaning and environmentally preferable to chemical based cleaning products[4] . Similarly, as plastic water bottles attracted loud critics for clogging landfills, the Swiss brand Sigg promoted its reusable aluminum bottles as a perfect antidote that protects the environment with the slogan “After all, it’s not what you drink, but what you drink it in.”[5] The key takeaway for companies here is to accentuate the environmental performance of their existing product that is already greener than

[4] http://www.heinzvinegar.com/products-distilled-white-vinegar.aspx, accessed September 13, 2012.

[5] http://www.sigg.bg/en/design/simply-ecological-1, accessed September 12, 2012.

available alternatives in the marketplace by spreading the good news through marketing channels, and to ensure that the media picks up on their marketing campaign.

Using green marketing to sell products with more environmental benefits entails some risks of course. Overreaching in their sustainability claims can cause companies receive heaps of criticism and face accusations of greenwashing. Consider the experience of Green Mountain Power Corporation. Environmental groups have not hesitated to point out greenwashing when they have seen that the company has allegedly been using polluting combustion services (e.g., toxic landfill gases and industrial wood wastes) - rather than clean renewables like wind and solar power - for their renewable energy sources, which they have marketed as green energy[6] . Likewise, SIGG has been accused of misleading consumers regarding the environmental benefits of its aluminum water bottles when the company has been outed for failing to tell the public that its bottles contain bisphenol-A, a controversial chemical used to harden plastics that is linked to premature puberty in girls and diabetes[7] . Touting the green attributes of a particular product can also prompt comparison with the company's rest of the offerings. A large discrepancy in environmental performance of a company's green and brown products can inevitably undermine its legitimate environmental claims. In 2008, General Motors caught flack from activists for running advertisements heralding a gas friendly Volt® electric car while continuing to manufacture one of the most environmentally unfriendly car on the planet; Hummer®[8] . Companies that decide to positively communicate about the environmental performance of their products must

[6] http://www.boycottgreenmountain.com, accessed September 13, 2012.

[7] http://www.time.com/time/health/article/0,8599,1932826,00.html, accessed September 9, 2012.

[8] http://indications.wordpress.com/2009/07/14/the-new-gm-greenwashing-motors, accessed September 9, 2012.

be wise: While accentuating the positive of their green products, they also have to actively eliminate the negative environmental impacts of their operations as a whole. Otherwise, they will eventually be called as a "greenwasher" which can be serious, long-lasting and hugely detrimental to their sustainability credibility and reputation.

Another way to green up is to modify existing products in a sustainable way. This means carrying an existing product design toward less-environmental-impact outcomes by making small enhancements or "tweaks" in the "green" direction. The takeaway of this approach is to ratchet up a product's environmental performance by designing bad materials out of the "non-green" product by substituting conventional materials with greener ones or by redesigning the "non-green" product in a way so that "non-green" materials are not required. The companies adopting this strategy must identify the materials that cause harm to public health or environment during manufacturing, use or disposal, and then act to eliminate them and/or find out what alternative materials they can use that are still effective in the product but that don't create a problem. Once the choice of what materials will be in the product's life cycle is made, the rest comes up to replacing hazardous materials with better ones or redesigning the existing product(s) through phasing out these hazardous materials. For example, in reformulating their Windex® glass cleaner, SC Johnson was able to identify and then replace seven "restricted-use materials" with ones that were free of volatile organic compounds (VOCs). The reformulation not only eliminated $400,000$ pounds of VOCs but also increased the product's cleaning power by 30%[9] . Likewise, Wish-Bone has recently taken a step in lower-environmental-impact direction through redesigning their salad dressing bottles. The new Wish-Bone bottles use up to 20% less plastic that is estimated to save nearly 30 million bottles worth of plastic in the year ahead[10] . Said another

[9] http://api.ning.com/files/Greenlistcasefinal.pdf, accessed October 4, 2012.

[10] http://www.wish-bone.com/, accessed September 24, 2011.

way, greening up brings gradual improvements to existing products and provides safer benefits that are important to sustaining share among current consumers as well as getting green consumers to try a product.

On balance, Greening Up can be a boon to a company's success, offering a limited but important window to engage in achieving sustainability gains. From a business perspective, for example, it does not involve major investments or risks since a structured, predictable and stepwise process is used. This strategy revolves around an existing product: It requires turning the existing product over again and again to a more environmentally benign alternative - and perpetuating to work on an even greener one. Therefore, it to a great extent builds on existing R&D and product-development assets, as well as technical expertise, keeping investment costs within reasonable boundaries. For example, Frito-Lay installed solar panels on its SunChips® factory in Modesto, California - one of eight plants where SunChips® snacks are made - to track the sun from dawn to dusk, gathering all the energy they can and reducing company's dependence on fossil fuel[11] . Transferring that energy into heat helps the company to cook the wheat and heat the cooking oil used in SunChips® manufacturing process. In other words, without making radical changes in their production plant and manufacturing line, Frito-Lay keeps producing $145,000$ bags of SunChips® snacks every day that are better for the environment. Following this track also lowers companies' exposure to risk and reduces their vulnerability to uncertain events otherwise inherent in a completely different production environment. Instead of trying to anticipate the fragile manufacturing and market demand of a new green product, companies can turn their attention just to adding green features on their non-green offerings what would help broaden their appeal to green consumers.

[11] http://www.sunchips.com/healthier_planet.shtml, accessed September 25, 2011.

From a market standpoint, it is relatively easy to determine the possible number of steps needed to be taken to improve the environmental impact of an existing product by using available information such as feedback from user experiences, testing and market investigations. For instance, in their journey to develop a better bag over the past 5 years, Frito-Lay has avoided the amount of packaging they need to use by more than 5 million pounds - by means of package size optimizations, film thickness improvements, and seal changes - by continuously pricking up their ears to consumer concerns and ideas. Their next step in right direction has been to change the material used in their packaging films, and this attempt has ended up with the world's first 100% compostable chip bag. Those bags, however, have been noisy; they sound a bit louder than previous SunChips® bags. In response, the company has recently introduced a new, quieter, fully compostable chip bag. In other words, this strategy allows its followers to identify consumer preferences and integrate them as features into their existing offerings. This in turn tends to strengthen market positions of the established companies in the industry as they can expand their consumer base by bolstering their reputation as a responsible enterprise. The cited examples of successes in marketplace show how a systematic approach to greening up products can yield a number of dividends. Poorly executed, greened-up products may not necessarily translate at the supermarket shelf level, though. Shoppers can fail to appreciate greened-up versions of brown products as they cruise the aisles. In addition, it can be hard to hype the fact that "Our oven cleaners are 20% less toxic than last year's," even though better that may be for the environment and public health.

3.1.2 Greening Out Strategy

The Greening Out strategy is simply about building new offerings from scratch that are unabashedly green. It entails the development/invention of new design elements such as a change in a product component (or invention of an alternative component) combined with a new architecture/design for linking all. The company relentlessly puts its technological, managerial and marketing muscles with the incumbent public relations potential into an explicitly green product that is markedly different from its existing “non-green” product(s). Many mainstream consumer-products giants have been taking this route and introducing brand-spanking-new green products into the market. Toyota took this path when they developed Prius® in late 1997. When we get down to the basics, an automobile can be depicted as a metal box on four wheels that is powered by an internal combustion engine and propelled by gasoline. Yet, when we come to the Prius®, it is far apart in every other way - for instance, with respect to its advanced Hybrid Synergy Drive powertrain technology, Kammback design to reduce air resistance and lower rolling-resistance tires, among other design and technology innovations it encompasses. Similarly, Clorox became the first mainstream consumer-products company to launch a line of non-synthetic cleaning products, the Green Works® line, in 2008. Last but not least, P&G has started to address environmental concerns mostly via reduced packaging. Discovering that their laundry detergent Tide® could make U.S. households energy guzzlers (due to the amount of energy required to heat water for washing clothes), the company made the development of cold-water detergents a priority and launched Tide Coldwater® in 2005.

Success along this strategic path requires specialized knowledge, competency in dealing with sustainability issues, credibility among green consumers and effective communication skills. It engenders significantly higher risks (especially at early stages) and a longer time horizon as compared to the Greening Up strategy, since companies on this path move into the new green markets that lie beyond their traditional expertise. A raft of quality problems uncovered in the steering of the first generation Toyota Prius® vehicles typifies this risk. The higher level of uncertainty (e.g., technical, market and organizational) inherent in almost every stages of this approach can be an enormous barrier to the reaping the sweet harvest of the efforts. More importantly, Greening Out can be the costlier approach; the company expends significant resources in terms of organization, concept generation, product, tooling, testing, marketing plan creation and evaluation, commercialization and the eventual introduction of the new product into the market. For instance, Clorox spent three years and more than $20 million to develop the Green Works® line, delaying the launch twice to ensure that all five original products performed as well as or better than conventional options in blind tests. They also had to tackle several marketing issues before launching the Green Works®.

This option appears to be more volatile, its outcomes tend to be more uncertain, and the time horizon also turns out to be much longer than Greening Up. On the other hand, this approach gives companies a helping hand to address consumers' environmental concerns in detail in their products/operations, and more importantly fosters the development of valuable (and even inimitable) competencies that can differentiate them in green market and ensure their competitiveness for years to come. Consider the case of the Prius® from Toyota. Toyota's bold decision to green light the Prius® - while Honda Insight® was striking but not earth shattering at the time - has paid handsome dividends. The efforts put by the company in the development of the Prius® have helped them to build valuable competencies (particularly in powertrain and electrical architecture), which in turn let the Prius® dominate the fast-growing market for hybrid cars in the U.S. - ahead of hybrid rival Honda Insight®, the first hybrid introduced in the U.S. market. In addition, the hybrid expertise and green know-how have begun to filter in other brands in Toyota's portfolio (e.g., Lexus®), taking the edge off development costs that were rumored to be on the high side of astronomical. Similarly, Green Works® allowed Clorox to accumulate a wide array of new competencies. Just a few examples include specialized knowledge about the preferences of environmentally conscious consumers and expertise in the supply chain for the procurement of natural products.

The potential opening of new green market segments, often exhibiting high growth potential, for an organization to pursue does appear to make this strategy tempting. When it works, as in the case of the Prius® or Green Works®, it could provide sustainable long term benefits. The combination of a green and a brown brand in the overall consumer market allows a company to calibrate those offerings to its own strategic advantage, and even to limit its troubling competitors in scope. However, this strategy does have some downsides. A green brand has its genesis in the recognition of consumers' evolving preferences. The subsequent development, introduction and marketing of the product should stay focused on this target consumer segment, and lack of experience in this rapidly growing market can render the green product's failure. The switch of management's focus to the green consumer segments that the green product is targeting can further cause a company to miss the mark with its existing consumers and this in turn may render company's existing products vulnerable. More importantly, the financial investment made on green brands can contribute to the difficult straits that a company finds itself in on this path. The launch, marketing communications, hiring and/or training of staff and operating costs can result in significant cash flow problems. That's why building green offerings from scratch appears to be a viable possibility for companies that are well equipped with their history of frequent product launches, substantial new product development assets and environmentally-conscious workforce, and that enjoy rapid turnover of products.

3.1.3 Greening Over Strategy

In an era where consumers are increasingly hyper-conscious of "going green", managers have suddenly found themselves facing a fork in the road: Should they tackle consumers' environmental concerns by redesigning their products (or product packaging) using less hazardous materials or substituting the bad materials with more environmentally sound alternatives? Or should they develop a new green brand from scratch? While it is already a challenging quandary, many companies are now considering a third option: taking over someone else's green brand. The quite shifts in the ownership of brands (and surprising connection of brands that seem unrelated to each other) is nothing new. Many brands recognized for their green assets, and environmentally responsible and counter-culture approach have been taken over by well-established corporations that are keen to establish credentials in the booming green market since 2000. Just a few examples include The Body Shop (acquired by the French cosmetics giant L'Oreal), Tom's of Maine natural personal-care products (Colgate-Palmolive), Stonyfield Farm Yogurt (Danone), Aveda cosmetics (Este Lauder), Green & Black's organic chocolates (Cadbury Schweppes), Ben & Jerry's ice cream (Unilever), Cascadian Farm cereals (General Mills) and Burt's Bees personal-care line and Brita water filters (Clorox). The growing list of these acquisitions shows that it is an attractive strategy for many companies, with its pluses and minuses. Carefully executed, this strategy can enable companies to "go green" relatively quickly.

In such deals the buyer is often expected to leverage its elusive distribution network capabilities onto the green brand to help him reach new markets faster - compared to its self-funded growth - and broaden its green costumer base. When structured properly, it also provides a quick access to the managerial capabilities of the buyer. Therefore, this route can effectively marry the brand integrity and environmental know-how of the green brand with the capital, and managerial systems and capabilities of the buyer. In its best applications such relationships can have even more impressive results. After Cadbury tapped into the consumers' appetite for organic chocolate through acquiring Green & Black's in 2005, sales of the organic chocolate maker have blossomed to 40 million pounds in 2011 in the UK, and the company is expected to hit the U.S. market this year with the financial support from Cadbury[12] . In like vein, Unilever's takeover of Ben & Jerry's has been a financially successful endeavor. Within the first three years following Unilever's acquisition, Ben & Jerry's increased its global sales by 37%, tripled

[12] http://www.independent.co.uk/news/business/analysis-and-features/cadbury-deal-turns-sour-for-green-amp-blacks-2187044.html, accessed September 21, 2011.

its operating margins and expanded into 13 new countries[13] . These deals, without doubt, are win-win situations; buyers are also positively impacted by these purchases. In its battle against Nestle, Unilever was in need of a good supply of ammunition to become the largest ice-cream company in the world, and had finally one-upped Nestle (Haagen-Dazs) through taking over Ben & Jerry's. As a parent company, Unilever has also seen substantial financial gains that stemmed primarily from the well-defined culture and established customer base of Ben & Jerry's. Although Haagen-Dazs outspends Ben & Jerry's in marketing dollars by 25% to 50%, both brands command an equal market share[14] .

Not all greening over stories reflect success. For the most part, the history of takeovers is a roll call of campaigns that not only inflicted damage on the buyers but also resulted in collateral losses for the green brands. There is no doubt takeover is appealing to big companies that seek out ways to enter the growing green markets that accompany without redesigning their current products and/or processes. Indeed, it may be the most and only effective route if they are not good at exploring significantly new ideas and radically different business approaches. Hence, under this strategy, a company acquires a ready-made package of a carefully crafted green brand image, specialized know-how about environmentally friendly innovation and manufacturing, green product development and a loyal customer base. In other words, the buyer hedges its bets at relatively low operating costs.

The buyer's main challenge here is to stay above the fray by maintaining the green brand's roots and cachet, and preventing its environmental/social reputation from taking a battering. An integral part of the green brand's success and distinctiveness

[13] http://www.workforce.com, accessed September 22, 2011.

[14] J. Bloom, "Ben & Jerry's Secret Formula for Marketing: No Apologies," *Advertising Age*, 8 August 2005.

is rooted in the environmental/social values it brings to the market, and so the buyer should stay away from piling in. The buyer should recognize that it does not have the mastery/competency over the green products/technology, and therefore it needs to let the green brand operate as an independent entity and let its green credentials/principles remain intact. Concentrating on cost rationalizations, and failing to understand/respect green brand's distinctive operating culture and environmental values may have an adverse effect on the courting and subsequently sour the marriage. In corporate marriages, a deliberate and careful search for a complementary partner also plays an important part as a takeover can seriously stumble when company cultures clash. The green consumers can feel betrayed by the green brand when they discover that their former ally has been swallowed by a vilified non-green company with its poor environmental credentials, and the scrutiny of green consumers may be a serious threat to the potential benefits of the takeover. When The Body Shop was sold out to L'Oreal in 2006, it spurred debate and protest amongst its consumer base, and L'Oreal has faced boycott campaigns over issues such as animal testing. Green technology and/or products can be unreachable and very difficult to replicate for big companies, and at these times takeover can be considered as an efficient path to the emerging green segments and business approaches. However, there are also nasty bumps along this path, and so companies should be very careful on their way to capturing the potential synergies in their marriage.

3.2 Choosing the Best Strategy

As discussed, Greening Up, Greening Out and Greening Over are all valid approaches, with their pluses and minuses, for companies that are eyeing green consumers and targeting the green marketplace. However, there is a bigger story here for companies that are seeking to reach out to the booming green market with their greener offerings to beef up their bottom lines and boost their top-line revenues. A one-size-fits-all strategy does not exist in this sizeable green market. The company managers must always keep in mind that these three strategies of going green work best under different market and business conditions, and require different technical competencies, resources and potential partnerships. Each of these strategies has merit, but they all come at the cost of unique challenges that require the development of specific competencies.

Simply put, regarding the Greening Out strategy, the failure to develop and launch a new green product puts brown companies - particularly the established ones - at risk of being knocked out of the competitive green landscape forever. While prospective green technologies and environmentally benign products are attractive along several dimensions, they are also highly resource intensive, comprised mainly of unprecedented features that are not fully proven and risk laden. Greening Out provides a new platform (i.e., blooming green market) for the long-term growth that many companies desperately seek when it is implemented properly, yet it is typically plagued by high uncertainty. Indeed, many companies, under pressure to maximize their short-term financial performance, are reluctant to invest in Greening Out due to various risk factors including technical risks (e.g., new green product may not perform as expected), market risks (e.g., green consumers may not respond to the new green product as expected), and organizational and resource risks. Attempts at Greening Out drive companies closer to the verge of failures than successes, and compel them to deal with high uncertainty in the timing and effectiveness of results. The movement of a new green product from a scratch paper to the green market can take several years, after which the product's market success is an unknown. In addition, credibility on the issue of company's and its new green product's environmental claims is a necessity for the acceptance of a new market formed by consumers who are espousing environmental values. By greening out, a company can have an enormous head start over its potential competitors in green market and create a step change in its revenues. However, in light of timing and uncertainty issues, many managers do not opt for greening out and prefer instead to pursue green markets through greening up their existing products or gaining access to green markets by takeovers.

On other other hand, Greening Up might not be a difficult choice for companies as Greening Out. Even though Greening Out often makes headlines, making stepwise changes to its existing products and technologies in the right direction can help a company outmaneuver the competitors in green market over the short term - with its existing product platforms. Greening Up allows companies to address the ever-changing needs and preferences of green consumers and keeps cash flows healthy. Compared to Greening Out, it is less ambitious in its green scope, does offer less potential for sustainability gains - achieves small degrees of growth, and consists of small endeavors, making them easier to manage. Contrary to the long and windy road followed by Greening Out, an environmental tweak on an existing product is placed within a clearly defined production process in a relatively shorter time period. Development of the greener product, and company's investment and marketing efforts are generally directed along an orderly and well-defined stage-gate approach. The companies are more likely to be less vulnerable to technical problems (e.g., major setback in green technology development), market uncertainties (e.g., failure to successfully develop a relationship with green consumers), and financial storms (e.g., major loss of funding due to the failure of a new green product). However, it may lead to a loss of competitive advantage in green landscape over time. New green products and green technologies of the competitors in green market appearing on the horizon may cause the followers of Greening Up to be undermined by companies who preferably follow Greening Out or Greening Over over the long term.

Companies with record levels of cash and only limited value-creating investment opportunities for new attractive green products rightly turn to Green Over to meet goals they cannot achieve internally (e.g., building a competitive position in emerging green markets). They takeover someone else's green brand with loyal customer bases, specialized knowledge about environmental innovation and manufacturing, and green market development to serve as a platform for transformative growth - just as they could if they followed Greening Out. Properly executed, it is faster, less risky and more economical to buy an attractive green product that the companies could make themselves, given enough time and resources. A buyer can boost its company performance or jump-start its long-term growth in green market with limited green expertise in the blink of an eye. The prospect of robust growth in Greening Over is very appealing, but the buyer should carefully evaluate the risk that their anticipated synergies with the seller may not materialize. A counter-cultural workforce, an iconic founder, scrutiny by green consumers, or some other aspect can create culture clash. In addition, the takeover can stumble if the buyer cannot preserve the integrity of the seller brand. It is also worth noting that the buyer and its green claims should be highly credible in Greening Over strategy, because acquired green consumers have to view the buyer as a credible steward of the seller brand.

Based on this discussion, the managerial choice among these strategies is obviously a function of multiple factors. This is summarized in Table 3-1, which hypothesizes how these facets drive each strategy choice. For example, if a company possesses inherent green product development capabilities, it is more likely to choose the Greening Out strategy and least likely to choose the Greening Over strategy. On the other hand, if the firm has significant cash reserves, then the Greening Over strategy becomes a more feasible choice as compared to the Greening Up or Greening Out strategy choices.

Table 3-1. Green product development strategies

	Paths to green product development		
	Greening-Up	Greening-Out	Greening-Over
Green product development capabilities	Low	High	N/A
Investment	Low	High	Variable
Technical risks	Low	High	Variable
Green expertise	Medium	High	Low
Market uncertainty	Low	High	Low
Time to market	Medium	High	Low
Marketing efforts	Low	High	High
Threat of greenwashing accusations	High	Medium	Low
Sustainability gains	Low	High	High

CHAPTER 4
DOES "TO GO GREEN" TRANSLATE INTO PROFITABILITY?

4.1 Overview

Does going green translate into increased profitability? Or is this simply an additional cost of doing business which will in all likelihood translate to higher consumer prices in the long run? These fundamental questions are being posed repetitively in the current business environment since most firms are including "green" product(s) in their product portfolio. This trend appears to be driven by multiple factors. First, there is a growing segment of customers who prefer green products (e.g., Klenier (1991)) and in several cases, these consumers are also willing to pay more for these environmentally friendly choices[1] . Second, green product development is also stimulated by environmental regulations and governmental incentives which prompt firms to add green products into their portfolios. As pointed out in Section 1.3.2, federal, state and local governments develop environmental policies, and pass laws and regulations (e.g., RoHs and EuP) that can impact directly or indirectly on the products and services of suppliers and end-product manufacturers by putting greater pressures on companies to adhere to the environmental standards in their product designs. Similarly, the European Union (EU) puts sustained efforts to advance environmental protection through increased products regulation. The EU has in recent years adopted legal measures that condition market access for automobiles, household appliances, electronic equipment, and biotech products on compliance with new product-based environmental requirements. In the coming years, the EU is expected to adopt additional measures that would similarly regulate imports of chemicals, energy using products, and certain timber products.

[1] GreenBiz.com, "Several Studies Say Conscious Consumers Willing to Pay More for Green," June 2009.

Third, initiatives being implemented by supply chain partners should stimulate green product development in the near future. For example, Lee Scott, CEO of Wal-Mart, states "A supplier that cheats on overtime and the age of its labor, that dumps its scraps and chemicals in our rivers, that does not pay its taxes or honor its contracts will ultimately cheat on the quality of its products. And cheating on the quality of its products is the same as cheating on customers."[2] Related to this statement, every new supplier agreement entered into by Wal-Mart is expected to require: (a) manufacturing facilities must certify compliance with laws and regulations where they operate as well as rigorous social and environmental standards, set by government agencies; (b) suppliers must work with Wa-Mart to make at least 20% improvements in energy efficiency by 2012; and (c) all suppliers must source at least 95% of their materials from production plants that receive the highest ratings on environmental and social practices. Finally, due to industry interest in sustainability/green issues, the concept of cradle-to-cradle certification has also started gaining more attention. According to McDonough Braungart Design Chemistry (MBDC), "The Cradle to Cradle framework moves beyond the traditional goal of reducing the negative impacts of commerce ('eco-efficiency'), to a new paradigm of increasing its positive impacts ('eco-effectiveness')."[3] This has also motivated organizational interest in investigating the impact of adding green products to its current assortment.

This chapter starts with an analysis of two alternative strategies that can be pursued by a firm to introduce a green product into the market. Key features incorporated in this analysis are as follows. First, under the proposed demand model, the market share for a given product depends on its quality and price (and the quality and price of every product in the assortment in case the firm is offering more than one product). Second,

[2] http://www.cio.com/article/print/456625, accessed July 22, 2010.

[3] http://mbdc.com/detail.aspx?linkid=1&sublink=6, accessed August 27, 2012.

while studying the pricing and marketing decisions of a firm, focusing on a single aggregate measure of green quality allows the obtained results to be applicable across a wider variety of settings. Third, cost effects specific to each strategy choice are explicitly integrated into the analysis and hence, insights reflect the implementation of each strategy in practice. Finally, motivated by the governments' environmental mandates on product design, the impact of stringent product-based environmental regulations on the financial performance of each strategy choice is investigated. In the second part of the chapter, the analysis is extended to a duopoly setting where two firms compete on the basis of price and green quality. In this environment, the analysis makes an attempt at characterizing a competitive equilibrium under different combinations of strategy choices with a view to provide further guidelines on strategy choices.

The remainder of this chapter is organized as follows. In the next section, alternative green product introduction strategies proposed by Unruh and Ettenson (2010) are discussed. Section 4.3 studies the profit maximization problem for each strategy choice, characterizes the optimal solutions, provides insights into the strategy choices for a single firm, and evaluates how financial performance of each strategy choice is moderated by environmental regulations. In Section 4.4, the impact of duopoly competition on strategy choices where firms compete under alternative green product strategies is examined. Finally, Section 4.5 contains concluding remarks.

4.2 Green Product Introduction Strategies

According to Unruh and Ettenson (2010), the choice of a green product development strategy is moderated by two factors: (a) the level of green attributes in the current product offerings; and (b) the inherent green process capability of the firm. Based on this categorization, their industry case studies indicate that successful firms make the choice as follows.

- If a firm has *low* inherent green process capability, then;

- if the firm's current product portfolio has a *low* green component, it should choose to acquire another firm which already offers a green product to the market. Example acquisitions include PTC (with its acquisition of PlanetMetric), Siemens (with its acquisition of Solel), and Honeywell (with its acquisition of E-Mon, LLC). This strategy is referred to as the Acquire strategy.
- if the firm's current product portfolio has a *high* green component, it should choose to accentuate the green attributes of this product portfolio through marketing efforts. For example, Britta water filters as noted by Unruh and Ettenson (2010) is a case in point. Given that the sales of water filters were being threatened by the use of bottled water, the company noted the adverse consumer reaction to the clogging of landfills with the plastic bottles. Sensing an opportunity, the company invested in a communications effort directed at pointing out the advantages of using their water filters as compared to bottled water and this resulted in significant sales increases for its product. This strategy is referred to as the Accentuate strategy.

- If a firm has *high* inherent green process capability, then;

  - if the firm's current product portfolio has a *low* green component, it should choose to architect a new green product in-house. The degree of green content in the new product is a managerial decision, and in some cases it could result in the firm introducing a completely new product (e.g., Caterpillar marketing new sustainable products through a focused business unit), or a partial redesign of an existing product (e.g., Toyota Prius®). This strategy is referred to as the Architect strategy.
  - if the firm's current product portfolio has a *high* green component, the choice among strategies is unclear. That is to say, the best strategy choice could be any one of the strategies outlined above.

Although these strategy choices are intuitively reasonable and industry case studies support the proposed framework, there are some further issues of relevance. First, since it is possible for a firm to be characterized by *high* inherent green process capability and *high* green product attributes in its current portfolio, how should the firm make a strategy choice in this setting? Second, are there additional factors (e.g., market size and strategy specific costs) that need to be incorporated when a firm evaluates these strategies, and if so, how is the strategy choice moderated by such factors? Based on these observations, this chapter focuses on a firm with substantial new-product-development assets that (i) currently offers a brown product to the market which already has environmental attributes that are just waiting to be leveraged; and (ii) is trying to incorporate environmental friendliness into its product design by adopting one of the two strategies described earlier - specifically the Accentuate and Architect strategies[4] .

4.3 The Monopolist's Strategy Choice

4.3.1 Preliminaries

In order to model a consumer's product choice decision, the prior work in *models of discrete (or quantal) choice* is drawn upon and specifically the *multinomial logit* (MNL) choice model is used. The MNL determines the choice probability as a function of consumer utility for a set of alternatives. For $n \geq 1$ products, a customer is assumed to associate a utility υ_i with product $i \in \{1, \dots, n\}$ defined by $\upsilon_i = \eta_i + \xi_i$, where we choose to express the term η_i as a linear function of observed attributes of product i, namely quality q_i and price p_i, such that[5] $\eta_i = q_i - p_i$. The random term ξ_i represents the unobservable utility or idiosyncratic preference of each customer[6] . Therefore, an individual consumer's utility for product i includes two facets: η_i represents the homogeneous valuation of all consumers, and ξ_i reflects the heterogeneity of consumers' valuation. Assume that the random terms $\{\xi_i\}$ are independent and

[4] The feasibility of the Acquire strategy is not evaluated since this strategy would require more of an industry level analysis rather than a firm level analysis. For example, the implementation of such a strategy would require a strategic analysis of how well the target firm and its products/processes "fit" into the current products/processes of the acquiring firm.

[5] A similar representation is used by McFadden and Zarembka (1974), Anderson et al. (1992) and Dong et al. (2009)).

[6] Notice that the utility function υ_i incorporates the idea that a customer prefers higher quality (lower price) levels as compared to lower quality (higher price) levels.

identically distributed Gumbel random variables with the function

$$P(\xi_i \leq \xi) = e^{\left(-e^{-\frac{\xi-\mu}{\psi}}\right)}, \quad \xi \in (-\infty, \infty), \tag{4–1}$$

where μ is a shift parameter and ψ is a scale parameter (e.g., Ben-Akiva and Lerman (1985) and Hanson and Martin (1996)). Without loss of generality, it is assumed that $\mu = 0$ and $\psi = 1$ for the analysis.

Based on this utility representation, the probability of a customer purchasing product i is[7]

$$\chi_i = \frac{e^{\eta_i}}{e^{\eta_0} + \sum_{j=1}^{n} e^{\eta_j}}, \qquad i = 1, \dots, n, \tag{4–2}$$

where e^{η_0} is the probability of the no-purchase outcome. It is assumed that $\eta_0 = 0$ and hence[8] , $e^{\eta_0} = 1$. Therefore, the probability of a no-purchase decision χ_0 is given by

$$\chi_0 = \frac{1}{1 + \sum_{j=1}^{n} e^{\eta_j}}. \tag{4–3}$$

The analysis here is carried out assuming a market size of 1 which implies that the choice probability can be interpreted as the market share associated with each product offering.

Let the index k represent each strategy choice ($k = C$ references the current setting, $k = A$ references the Accentuate strategy, and $k = B$ references the Architect strategy). The modeling assumptions can be summarized as follows. First, the marginal costs of production are assumed to be related to the quality level of the product. In line with the argument put forward by Moorthy (1984) that production cost increases at a

[7] See Ben-Akiva and Lerman (1985) for a derivation of the choice probability in detail.

[8] This representation is also adopted by Chintagunta (2002)

faster rate than the consumers' willingness to pay, the unit cost of production is assumed to be convex and strictly increasing in the quality level q that is reflected by a specific function αq^2 with $\alpha > 0$. Second, higher advertising expenditures have been associated with higher quality levels in prior research (e.g., Milgrom and Roberts (1986)), and Sutton (1991) empirically characterizes advertising costs as a function of product quality. Drawing upon this work, it is assumed that total advertising costs are an increasing function of quality, represented by $\gamma q^2/2$, where $\gamma > 0$[9] . Being consistent with the previous literature on product redesign (e.g., Krishnan and Lecourbe (2010)), the final assumption is that total product redesign costs are increasing and convex in quality as reflected in the functional form τq^2 with $\tau > 0$.

Recall that governments have a direct stake in eliminating and preventing the negative environmental impact of products, and hence, they can regulate product designs based on their sustainability or their external cost to the environment. This aspect is integrated into the analysis in this chapter as follows. Define q_e as the "green" quality and q_b as the "non-green" quality in a product portfolio/assortment. Then, the operationalization of the regulatory constraint is given by

$$\frac{q_e}{q_b} \geq \sigma \tag{4–4}$$

where $\sigma > 0$ reflects the minimum percentage of "green" quality which must offered in the product portfolio/assortment. Although there are several possible methods to operationalize a regulatory constraint, having the above choice is intuitively reasonable since it expresses the "green" quality level in reference to the current level of "brown" quality and hence, it should be applicable across a variety of settings. For instance, as for fuel efficiency, in August 2012, the Obama administration issued the final version of

[9] Given that Sutton (1991) empirically derived the relationship $M(q) = \frac{\gamma}{z}(q^z - 1)$ with $z > 1$, the functional form held here obviously satisfies this relationship with $z = 2$.

regulations that force automakers to nearly double the average fuel economy of all new cars they sell in the U.S. so that the new standards mandate an average fuel economy of 54.5 miles per gallon, compared to 29.7 miles per gallon now[10] . Then, if product quality represents the average gas mileage, the recently finalized governmental regulation on fuel efficiency is captured by setting the value of the parameter σ equal to 2. In this setting, the higher values of σ implies the enforcement of stringent environmental regulations on the product design, while lower values of σ indicates the use of weak environmental standards.

In the next three subsections, initially the current scenario where a brown monopolist firm offers a single brown product is examined, and then the two green strategy choices for the monopolist firm (i.e., Accentuate and Architect strategies) with and without the enforcement of environmental standards are characterized. This is followed by a numerical analysis comparing the current scenario and two strategy choices under weak environmental standards, and then evaluating how profitability of each strategy choice is affected when environmental regulations are tightened.

4.3.2 Current Scenario: Single Brown Product

In this section, the setting for a monopolist brown firm offering a single brown product, of quality q_b, to the market at price p_b is analyzed. Given that the firm currently supplies a single brown product with high greeneable environmental benefits in a monopolistic environment, the market share of the brown product is defined as $\chi_b^C = e^{q_b - p_b}/(1 + e^{q_b - p_b})$. The profit maximization problem in this setting can then be stated by $\Pi^C = \chi_b^C \left[p_b - \alpha q_b^2\right]$ with $p_b, q_b \geq 0$. Based on the first-order conditions (which are necessary and sufficient since the profit function is strictly and jointly concave in the

[10] Bill Vlasic, "U.S. Sets Higher Fuel Efficiency Standards," *The New York Times*, 28 August 2012.

decision variables), the optimal brown quality embedded in the product is:

$$q_b^* = \frac{1}{2\alpha} \tag{4–5}$$

and the optimal price p_b^* is given by the (implicit) solution of the following equation;

$$p_b^* = \frac{1}{4\alpha} + \frac{1}{1 - \chi_b^{C*}}, \tag{4–6}$$

where

$$\chi_b^{C*} = \frac{1}{1 + e^{p_b^* - \frac{1}{2\alpha}}}. \tag{4–7}$$

Therefore, the corresponding optimal profit for the firm is $\Pi^{C*} = \chi_b^{C*}/(1 - \chi_b^{C*})$ with χ_b^{C*} as defined above.

4.3.3 Accentuate Strategy

Under this strategy choice, two primary decisions for the monopolist firm are: (a) the level of the environmental benefits of the existing brown product which should be accentuated; and (b) the revised market price for the current brown product offering which will now be perceived as better for the environment. These decisions are related to the optimal quality and price of the current brown product as follows:

- Let q_b^A represent the perceived quality of the accentuated brown product and it integrates two aspects: (a) the current brown component $q_b^* = \frac{1}{2\alpha}$; and (b) the accentuated green component q_e^A. Then, $\eta_b^A = q_b^A - p_b^A$, where q_b^A is defined by $q_b^A = q_b^* + \theta q_e^A$ (or $q_b^A = \frac{1}{2\alpha} + \theta q_e^A$) with $0 < \theta \leq 1$. Note that $\theta \in (0, 1]$ means an individual consumer places a lower value on environmental attributes compared to traditional attributes and so does not fully integrate green issues into his product value calculation.

- The firm can revise the market price for its accentuated brown product to cover additional marketing costs $\left[\frac{\gamma}{2}\right] \left(q_e^A\right)^2$, and p_b^A represents the revised price.

Based on the above considerations, the market share χ_b^A of the accentuated brown product is given by

$$
\begin{aligned}
\chi_b^A &= \frac{e^{q_b^A - p_b^A}}{1 + e^{q_b^A - p_b^A}}, \\
&= \frac{1}{1 + e^{p_b^A - \frac{1}{2\alpha} - \theta q_e^A}},
\end{aligned} \tag{4–8}
$$

and the monopolist firm's profit maximization problem under the Accentuate strategy choice gets the following form:

$$
\max_{p_b^A, q_e^A \geq 0} \Pi^A = \chi_b^A \left[p_b^A - \alpha \left(q_b^*\right)^2\right] - \left[\frac{\gamma}{2}\right] \left(q_e^A\right)^2 \tag{4–9}
$$

$$
\text{subject to} \quad \frac{q_e^A}{q_b^*} \geq \sigma \tag{4–10}
$$

with χ_b^A is as given in equation (4–8) and $q_b^* = 1/(2\alpha)$. The theorem below characterizes the solution to this problem.

Theorem 4.1. *Assuming that Π^A is strictly and jointly concave in p_b^A and q_e^A (detailed in appendix);*

- *If regulatory constraint is non-binding, then the optimal value of q_e^A is given by the (implicit) solution of the following equation;*

$$
\mathcal{G}\left(q_e^A\right) \equiv e^{\frac{\theta}{\theta - \gamma q_e^A} - \theta q_e^A - \frac{1}{4\alpha}} - \frac{\theta}{\gamma q_e^A} + 1 = 0, \tag{4–11}
$$

based on which the optimal value of p_b^A can be obtained as follows:

$$
p_b^{A*} = \frac{1}{4\alpha} + \frac{\theta}{\theta - \gamma q_e^A} \tag{4–12}
$$

- *If regulatory constraint is binding, then*

$$
q_e^{A*} = \frac{\sigma}{2\alpha}, \tag{4–13}
$$

and p_b^A is obtained by the (implicit) solution of the following equation:

$$
\mathcal{L}\left(p_b^A\right) \equiv \left(p_b^A - \frac{1}{4\alpha} - 1\right) e^{p_b^A - \frac{1+\theta\sigma}{2\alpha}} - 1 = 0 \tag{4–14}
$$

Proof. See Appendix A. □

4.3.4 Architect Strategy

Under this strategy choice, the three primary decisions for the monopolist firm that is currently offering a brown product q_b^* at price p_b^* are:[11] (a) the green quality level that will be designed into the new product (i.e., q_e^B); (b) the market price for this new product offering (i.e., p_e^B); and (c) the revised market price for the existing brown product (i.e., p_b^B). From the market perspective, the logit-based consumer choice framework described earlier is followed and hence, the market share for the new green product $\left(q_e^B, p_e^B\right)$ is equal to $\chi_e^B = e^{\theta q_e^B - p_e^B} / \left(1 + e^{\theta q_e^B - p_e^B} + e^{q_b^* - p_b^B}\right)$. Note that while expanding its product line with a green alternative, a brown firm can leverage the price of its existing brown product due to the threat of cannibalization within the product line. For that reason, in this analysis the firm is allowed to modify the price of its existing brown product under the Architect strategy[12] . Then, the market share of the firm's current brown product is $\chi_b^B = e^{q_b^* - p_b^B} / \left(1 + e^{\theta q_e^B - p_e^B} + e^{q_b^* - p_b^B}\right)$. As considered under the Accentuate strategy, the impact of regulatory compliance under Architect strategy choice is also incorporated by imposing an environmental regulation constraint on the quality of the firm's new green product such that

$$\frac{q_e^B}{q_b^*} \geq \sigma \tag{4–15}$$

with $\sigma > 0$. In terms of unit production costs, these are a function of the quality levels of the green and brown products, and are assumed to be $\alpha \left(q_e^B\right)^2$ and $\alpha \left(q_b^*\right)^2$, respectively. The advertising and product redesign costs for this strategy are $\gamma \left(q_e^B\right)^2 / 2$ and $\tau \left(q_e^B\right)^2$, respectively, based on the discussion in Section 4.3.1.

[11] The values of q_b^* and p_b^* are as provided in equations (4–5) and (4–6) in Section 4.3.2.

[12] By this stage, the quality of the existing brown product is fixed at $q_b^* = 1/(2\alpha)$ as it is determined in the product design phase and it takes a longer time period to change quality compared to price.

In this framework, the monopolist's profit maximization problem under the Architect strategy choice is:

$$\max_{p_e^B, q_e^B, p_b^B \geq 0} \Pi^B = \chi_e^B \left[p_e^B - \alpha \left(q_e^B \right)^2 \right] - \left[\frac{\gamma}{2} + \tau \right] \left(q_e^B \right)^2 + \chi_b^B \left[p_b^B - \alpha \left(q_b^* \right)^2 \right] \quad (4\text{–}16)$$

$$\text{subject to} \quad \frac{q_e^B}{q_b^*} \geq \sigma \quad (4\text{–}17)$$

with $q_b^* = 1/(2\alpha)$. The theorem below characterizes the solution to this problem.

Theorem 4.2. *Assuming that Π^B is strictly and jointly concave in p_e^B, q_e^B and p_b^B (detailed in appendix), and given that $q_b^* = \frac{1}{2\alpha}$, the profit margins of the brown and green products are equal so that $p_e^{B*} - \alpha \left(q_e^{B*} \right)^2 = p_b^{B*} - \alpha \left(q_b^* \right)^2$. Then;*

- *If regulatory constraint is non-binding, then the optimal values of the quality and price of the green product (i.e., q_e^{B*} and p_e^{B*}) satisfy the following equation:*

$$\theta = q_e^{B*} \left[2\alpha + (\gamma + 2\tau) \left(1 + e^{p_e^{B*} - \theta q_e^{B*}} + e^{\frac{1}{4\alpha} + \alpha \left(q_e^{B*} \right)^2 - \theta q_e^{B*}} \right) \right] \quad (4\text{–}18)$$

- *If regulatory constraint is binding, then*

$$q_e^{B*} = \frac{\sigma}{2\alpha}, \quad (4\text{–}19)$$

  and the optimal value of p_e^B is given by the (implicit) solution of the following equation:

$$\mathcal{W}\left(p_e^B \right) \equiv e^{p_e^B} \left(p_e^B - \frac{\sigma^2}{4\alpha} - 1 \right) - e^{\frac{\theta\sigma}{2\alpha}} - e^{\frac{1+\sigma^2}{4\alpha}} = 0 \quad (4\text{–}20)$$

Proof. See Appendix B. □

For all three cases described above, the optimal decisions can be structurally characterized. However, as is obvious, no direct comparison between the strategies can be provided in terms of market share, profits, and levels of green quality. For that reason, next section resorts to a numerical analysis to offer some insights into the choice among strategies.

4.3.5 Numerical Analysis

This sections starts with an analysis of the dominance relationship between the Accentuate and Architect strategies under sufficiently weak environmental standards to identify to what extent a firm chooses each strategy. This is followed by an analysis of how each strategy choice is moderated by the enforcement of stringent environmental regulations. The numerical comparison between strategies uses the following parameter settings:

- Unit production cost (α). The values of this parameter are set at $\$0.20, 0.40, 0.60, 0.80$, and 1.00.
- Consumer valuation of green attributes (θ). The values of this parameter are set at $0.20, 0.40, 0.60, 0.80$, and 1.00.
- Marginal advertising costs (γ). The value of this parameter is set at $\$4$.
- Marginal product redesign costs (τ). The values of this parameter are set at $\$2, 4, 6$, and 8.

For each combination of parameter settings[13] , the optimal prices and quality levels, market shares, profit margins, and the profit for the monopolist are tracked. The solutions are obtained using the EXCEL evolutionary solver. More specifically: (a) for the current setting, the optimal price p_b^* is obtained using equation (4–6); (b) for the Accentuate strategy, the optimal value of accentuated green component q_e^{A*} is obtained by solving equation (4–11) and the corresponding optimal price for the accentuated product p_b^{A*} is obtained by using equation (4–12); and (c) for the Architect strategy, first the optimal green product quality q_e^{B*} and price p_e^{B*} are obtained by using equation (4–18) and then using the result that profit margins for both the green product and brown product are equal, the optimal price of the brown product p_b^{B*} is determined.

Rather than presenting all the results, a sampling of some of the results for the current setting and each strategy choice are presented in Figures 4-1, 4-2, 4-3 and 4-4

[13] Here the value of σ is set such that the environmental regulation constraint imposed on the green quality level is never binding in order to concentrate on and clarify what factors a firm should consider when choosing between the Accentuate and Architect strategies. How stringent environmental standards impact on the financial performance of each strategy choice is analyzed in the following section.

(See Appendix C for complete results). In general, the following observations are worth noting. Across all parameter combinations, the Architect strategy dominates the Accentuate strategy that in turn dominates the current setting in terms of profitability and market share. Note that this dominance relationship holds even when the consumer valuation of green attributes is very low (i.e., $\theta = 0.20$), and marginal advertising and product redesign costs are very high (i.e., $\gamma = \$4$ and $\tau = \$8$) as shown in Figures 4-1 and 4-2. Thus, both Accentuate strategy (i.e., the marketing of green attributes) and Architect strategy (i.e., simultaneous introduction of a green product) reward the brown firm with profit and market share gains. These gains in profits and market share are dependent upon several factors. For example, as customers demand more environmentally friendly choices (i.e., $\theta \to 1$), the firm repositions its brown product as better for the environment by pursuing the Accentuate strategy. This enhances the perceived value of the existing brown product (even though its quality is fixed at $1/(2\alpha)$), and enables the firm to gain a larger market share, charge a higher price for the accentuated product and enjoy rises in profit margins (since production costs are constant based on the brown quality level). A simultaneous price increase for the brown product is the result when the Architect strategy is chosen over the current setting. However, in this setting, the firm loses the market share associated with its brown product (when comparing the current setting versus the Architect strategy) due to cannibalization effects, which is offset by the simultaneous introduction of a new green offering. This results in the firm commanding a greater total market share under the Architect strategy in comparison to the captured market share under current setting.

A second interesting result is in the context of comparing the optimal green quality specified in the accentuated product and green product offered under the Accentuate and Architect strategies, respectively. Across all parameter combinations, it is observed that the Accentuate strategy requires the firm to highlight a greater degree of green in its product as compared to the Architect strategy. In other words, while the Accentuate

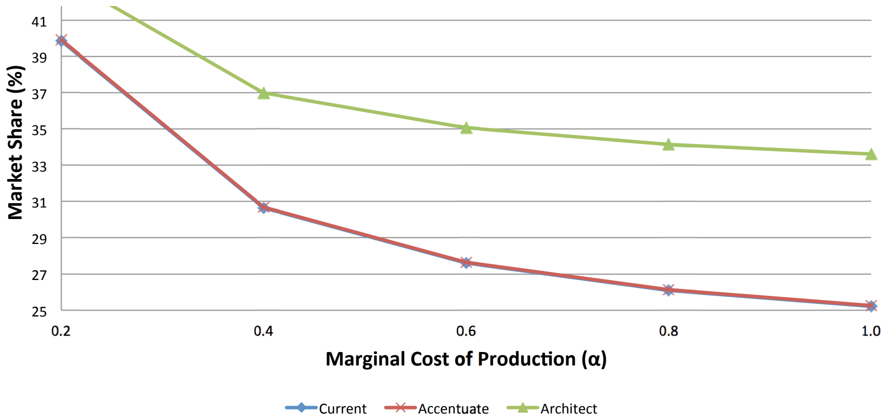

Figure 4-1. Comparison of profits of strategies ($\theta = 0.20$, $\gamma = \$4$ and $\tau = \$8$)

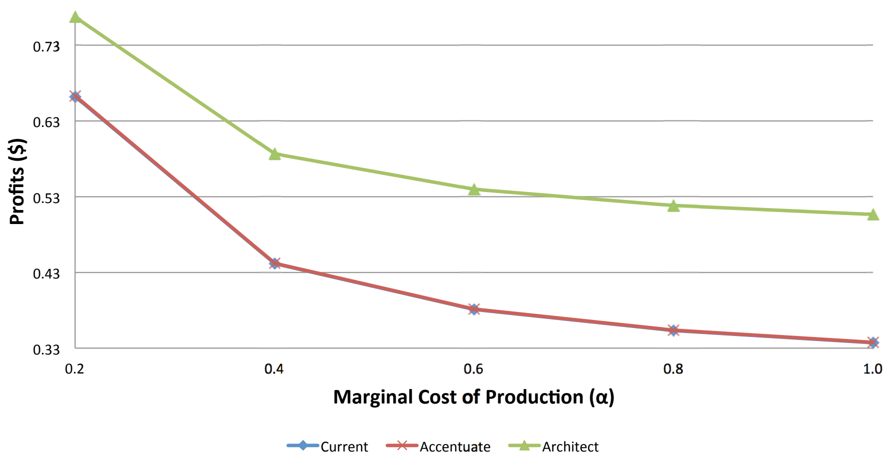

Figure 4-2. Comparison of market shares of strategies ($\theta = 0.20$, $\gamma = \$4$ and $\tau = \$8$)

strategy yields less total profits and market share than does the Architect strategy, it dominates the Architect strategy from a "green" perspective (see Figures 4-3 and 4-4). One underlying reason for this result is attributed to the fact that marginal costs of incorporating green in a product are lower under the Accentuate strategy (as it only includes costs of advertising) as compared to the Architect strategy (as it includes not only advertising costs but also product redesign costs). In essence, this result points out to a trade-off needed to be made between green quality levels and profits/market share. Given that both green strategies are preferred over the current setting, the Accentuate (Architect) strategy requires marketing (redesigning) a higher (lower) degree of green in the accentuated (green) product, whereas providing smaller (higher) profits and market share as compared to the Architect (Accentuate) strategy.

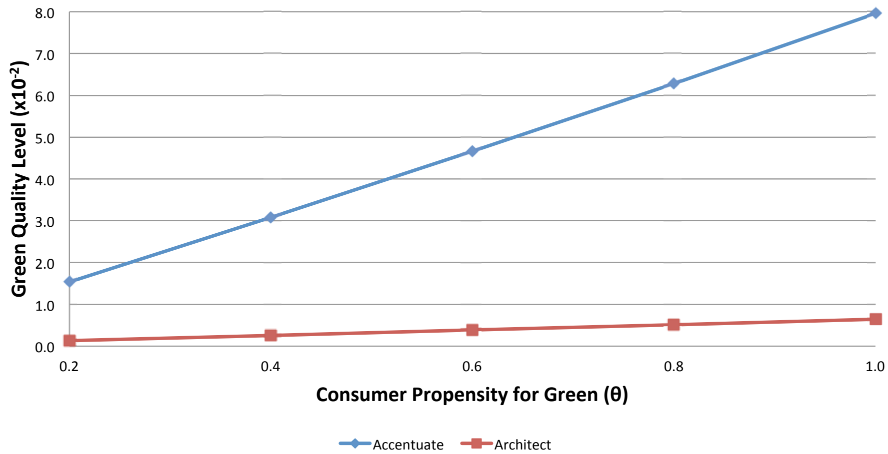

Figure 4-3. Comparison of green quality levels supplied by strategies ($\alpha = \$0.4$, $\gamma = \$4$ and $\tau = \$2$)

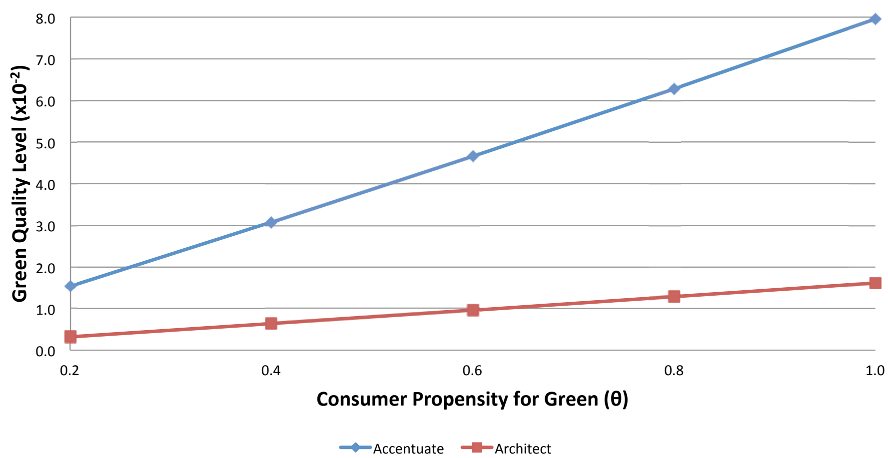

Figure 4-4. Comparison of green quality levels supplied by strategies ($\alpha = \$0.4$, $\gamma = \$4$ and $\tau = \$8$)

A final issue of interest explored here is the existence of extreme conditions which would result in the firm not choosing to adopt either the Accentuate and/or Architect strategies (i.e., choosing to *not* go green). It is obvious that assuming fixed market prices, an increase in environmental quality would lead to: (a) a greater market share; (b) a lower profit margin; and (c) higher advertising and/or product redesign costs. On the other hand, assuming fixed levels of quality, an increase in market prices leads to: (a) a smaller market share; and (b) a higher profit margin. It so happens that when the marginal costs of advertising and/or product redesign are extremely high, the firm's optimal green quality level drops significantly (and is close to 0). If this is the case, then the optimal choice for the firm is to revert back to simply offering only the brown product to the market and hence, in these extreme cases, the firm is actually better-off not accentuating the existing brown product or introducing a newly designed green product.

4.3.5.1 Impact of strict environmental regulations

The analysis of the impact of the regulatory constraint on the Accentuate and Architect strategies starts with the following observations. First, the regulatory constraint is binding only when the optimal green quality level for the unconstrained profit maximization problem for a strategy choice did not meet the regulatory constraint. Hence, under the binding constraint, the firm is required to choose higher levels of green quality. Second, assuming that regulatory constraint is binding for both strategy choices, the firm offers identical levels of environmental quality to the market (i.e., $q_e^{A*} = q_e^{B*} = \sigma/(2\alpha)$), and based on this result, the costs of advertising (incurred under the Accentuate strategy) and product redesign (incurred under the Architect strategy) are fixed. Apparently, the costs for the Architect strategy are higher than those for the Accentuate strategy, since the former includes both advertising and product redesign costs, while the latter includes only advertising costs. Finally, the only remaining decision for each strategy choice turns out to be the market pricing decision.

To gain some insights into this market pricing decision, it is observed that the firm will raise market prices to increase its profit margin. However, given fixed levels of green and brown quality, an increase in market prices will reduce market shares. Thus, the optimal market price will be such that it balances out these two effects. In all of the carried out numerical experiments, the following distinct effects are noted when the regulatory constraint is binding for both strategies:

- regardless of the strategy choice, the profit (and total market share) for the firm under a binding regulatory constraint is always smaller than the profit (and total market share) for the firm under the non-binding regulatory constraint;
- there are several instances where the firm could not recover the costs of advertising and/or product design, resulting in the firm profits being negative;
- for the Architect strategy, the imposition of the regulatory constraint leads to the firm increasing the market price of both products; while for the Accentuate strategy, the firm raises the market price for the accentuated product; and
- the Architect strategy still dominates the Accentuate strategy in terms of profits and market share.

These results are in line with industry observations. For example, the recent studies of the National Automobile Dealers Association (NADA) indicate that more stringent standards will hike the average price of a new vehicle by nearly $\$3,000$ when fully implemented. More importantly, NADA also states that approximately 7 million people will not be able to afford new cars, and if these standards suppress new vehicle sales, achieving the nation's greenhouse gas and every security goals will be needless delayed[14] .

A final result of interest is that the imposition of the regulatory constraint could moderate the optimal strategy choice for the firm. As observed earlier, when the regulatory constraint is not imposed, the optimal level of green quality is higher under the Accentuate strategy as compared to the Architect strategy (i.e., $q_e^{A*} \geq q_e^{B*}$). If the value of σ (i.e., the minimum proportion of regulated green quality) is set such that $q_e^{B*} < \sigma \leq q_e^{A*}$, then obviously there is no change in q_e^{A*} and corresponding market price p_b^{A*}, and thus the profits for the Accentuate strategy are not affected. On the other hand, there is a reduction in the profits for the Architect strategy, since the optimal green quality level is now set to meet the regulatory constraint. The numerical analysis here

[14] Brad Tuttle, "How the New MPG Standards Will Affect Drivers, Automakers, Car Dealerships & More," *Time*, 30 August 2012

indicates that under this scenario (i.e., $q_e^{B*} < \sigma \leq q_e^{A*}$), it is possible for the Accentuate strategy to dominate the Architect strategy in firm profits and market share, especially when σ is set such that it approaches q_e^{A*}, and at the same time, there is a significant difference between σ and q_e^{B*}.

4.4 Impact of Competition

To evaluate the impact of competition, this section concentrates on a duopoly where consumer choice is modeled using the multinomial logit approach. The key focus here is to understand how firms would compete under alternative strategy choices. The analysis is twofold. The first part analyzes the competition between two firms under different strategy choices: In the first two scenarios, it is proposed that one firm adopts the current setting (i.e., offers only the brown product to the market) and other firm chooses either the Accentuate or Architect strategy, and in the final scenario, one firm adopts the Accentuate strategy while the other firm adopts the Architect strategy. This is followed by the analysis of a duopoly setting where firms compete under identical strategy choices.

In order to analyze firm level decisions under each scenario, competition between firms is modeled as a simultaneous-product-choice model that analyzes firms' choices of quality and price in a two-stage game framework (e.g., Shaked and Sutton (1982) and Moorthy (1988)). In the first stage, each firm chooses the level of product quality simultaneously with the other firm, and in the second stage the firms simultaneously determine prices after observing each other's product qualities. Depending on the quality choice, prices can easily be adjusted, and so firms can anticipate the impact of the quality levels of their products on the resulting price competition. Thus, it is proceeded by backward induction in an attempt to define simultaneous price-quality equilibria for each firm. The MNL framework proposed previously in the monopolist setting is retained, but additionally it is assumed that all consumers always purchase one unit of their most preferred product in the marketplace (e.g., Guadagni and Little (1983)). Thus, a no-purchase option is no longer accommodated for consumers in this duopoly configuration which implies complete market coverage. From a cost perspective, it is also assumed that both firms are equally efficient in terms of the marginal cost of production (i.e., $\alpha_1 = \alpha_2 = \alpha$), marginal cost of advertising (i.e., $\gamma_1 = \gamma_2 = \gamma$) and marginal cost of product redesign (i.e., $\tau_1 = \tau_2 = \tau$). Finally, the regulatory constraint is not incorporated into the duopoly setting, since the primary focus here is on validating whether the strategy recommendations under the single firm setting hold in the presence of competition.

4.4.1 Current Setting - Accentuate Strategy

In this scenario, it is assumed, without loss of generality, that Firm 1 adopts the current setting (i.e., offers the brown product to the market) while Firm 2 adopts the Accentuate strategy (i.e., offers an accentuated brown product to the market). Hence, the key decisions for Firm 1 are the level of brown quality q_{b1}^C and the market price for the brown product p_{b1}^C, while for Firm 2, the corresponding decisions are the level of accentuated green quality q_{e2}^A and the revised market price for the accentuated brown product p_{b2}^A. Note that for Firm 2, the level of brown quality is fixed at $q_{b2}^A = 1/(2\alpha)$, which is in line with the analysis for the Accentuate strategy in Section 4.3.3. Given that all consumers buy their product from one of two firms, the market shares of Firm 1 and Firm 2 are given respectively as follows:

$$\chi_{b1}^C = \frac{\Delta}{1+\Delta} \quad (4\text{–}21)$$

$$\chi_{b2}^A = \frac{1}{1+\Delta} \quad (4\text{–}22)$$

where Δ is the ratio of the market share for Firm 1 to the market share of Firm 2 so that $\Delta = e^{-\left(\frac{1}{2\alpha}+\theta q_{e2}^A - q_{b1}^C\right)+\left(p_{b2}^A - p_{b1}^C\right)}$. Based on the market share functions, given q_{b1}^C and q_{e2}^A, each firm's profit maximization problem to set optimal prices is:

$$\Pi_1^C = \chi_{b1}^C\left[p_{b1}^C - \alpha\left(q_{b1}^C\right)^2\right] \quad (4\text{–}23)$$

$$\Pi_2^A = \chi_{b2}^A\left[p_{b2}^A - \frac{1}{4\alpha}\right] - \left[\frac{\gamma}{2}\right]\left(q_{e2}^A\right)^2 \quad (4\text{–}24)$$

The necessary conditions for optimum market prices charged by the two firms are:

$$\frac{\partial \Pi_1^C}{\partial p_{b1}^C} = 0 \quad \Rightarrow \quad p_{b1}^C = \alpha \left(q_{b1}^C\right)^2 + 1 + \Delta \tag{4–25}$$

$$\frac{\partial \Pi_2^A}{\partial p_{b2}^A} = 0 \quad \Rightarrow \quad p_{b2}^A = \frac{1}{4\alpha} + 1 + \frac{1}{\Delta} \tag{4–26}$$

so that $p_{b2}^A - p_{b1}^C = \frac{1}{4\alpha} - \alpha\left(q_{b1}^C\right)^2 + \frac{1}{\Delta} - \Delta$. Then, at the price equilibrium, the profit functions for each firm can be restated as follows:

$$\hat{\Pi}_1^C = \Delta \tag{4–27}$$

$$\hat{\Pi}_2^A = \frac{1}{\Delta} - \left[\frac{\gamma}{2}\right]\left(q_{e2}^A\right)^2 \tag{4–28}$$

In the first stage, the FOCs for each firm are:

$$\frac{\partial \hat{\Pi}_1^C}{\partial q_{b1}^C} = \left(\frac{\Delta^2}{1+\Delta+\Delta^2}\right)\left(1 - 2\alpha q_{b1}^C\right) \tag{4–29}$$

$$\frac{\partial \hat{\Pi}_2^A}{\partial q_{e2}^A} = \left(\frac{\theta}{1+\Delta+\Delta^2}\right) - \gamma q_{e2}^A \tag{4–30}$$

Setting these equal to 0, it is obtained

$$q_{b1}^C = \frac{1}{2\alpha}, \tag{4–31}$$

$$q_{e2}^A = \frac{\theta}{\gamma\left(1+\Delta+\Delta^2\right)}, \tag{4–32}$$

and substituting these values in the expression for Δ gives

$$\Delta = e^{\left(-\frac{\theta^2}{\gamma(1+\Delta+\Delta^2)} + \frac{1}{\Delta} - \Delta\right)}. \tag{4–33}$$

Lemma 1. *Given that $\theta \in (0, 1]$ and $\gamma > 0$, the value of Δ implicitly solving the equation $\Delta = e^{\left(-\frac{\theta^2}{\gamma(1+\Delta+\Delta^2)} + \frac{1}{\Delta} - \Delta\right)}$ must be strictly greater than 0 and strictly less than 1.*

Proof. See Appendix D. □

Given the result in Lemma 1 and that Δ is the ratio of the market share of Firm 1 to that of Firm 2, the firm choosing the Accentuate strategy (i.e., Firm 2) would garner a greater market share than the firm which chooses to continue offering the brown product (i.e., Firm 1). Although it is not possible to structurally characterize the existence of a unique equilibrium, the relative profitability of the two firms can be evaluated by using the result provided in Lemma 1. In order to do this, the value of γ is set equal to $\$4$, and then the value of θ is varied to be $0.20, 0.40, 0.60, 0.80$ and 1.00[15] . For each combination of γ and θ, initially the expression in equation (4–33) is solved to obtain a value of Δ. Using this value of Δ, the accentuated green quality level q_{e2}^{A} is then determined by using equation (4–32). Finally, these solutions are used to obtain the profits for both firms using equations (4–27) and (4–28), and these results are presented in Table 4-1. Table 4-1 shows that for all parameter combinations, Firm 2 always makes greater profits as compared to Firm 1. Hence, it always pays for a firm to choose to accentuate its current brown offering when it is in competition with another firm which is simply offering a brown product. Second, as would be expected, an increase in the marginal consumer valuation for green quality leads to increases in the green quality level accentuated by Firm 2, and also increases in the profits for Firm 2. One set of results not shown here are that a similar pattern holds even if we increase the marginal advertising cost parameter γ in terms of relative profits for the two firms (see Appendix E for complete results).

4.4.2 Current Setting - Architect Strategy

In this setting, an alternative duopoly scenario is analyzed, where Firm 1 only offers a single brown product to the market and Firm 2 adds a new green offering to its existing brown product. In line with the equilibrium concept studied in Section 4.4.1, the attempt here is to find an equilibria to the two-stage game, where Firm 1 chooses the quality of its brown product q_{b1}^{C} and Firm 2 chooses the quality of its new green product q_{e2}^{B} in the first stage, and both firms select the prices of their products in the marketplace

[15] These are the same numerical parameter settings used in the previous section.

(i.e., p_{b1}^C, and p_{b2}^B and p_{e2}^B) in the second stage. Following the argument put forward in Section 4.3.4, it is assumed that Firm 2 has the option of altering the price of its existing brown product at the time of introducing a new green product into the market, whereas its quality is fixed at $1/(2\alpha)$. The market share side is similar as in the duopoly market structure studied in Section 4.4.1 and so the market shares of the products are given as follows:

$$\chi_{b1}^C = \frac{e^{\left(q_{b1}^C - p_{b1}^C\right)}}{e^{\left(q_{b1}^C - p_{b1}^C\right)} + e^{\left(q_{b2}^B - p_{b2}^B\right)} + e^{\left(\theta q_{e2}^B - p_{e2}^B\right)}} \tag{4–34}$$

$$\chi_{b2}^B = \frac{e^{\left(q_{b2}^B - p_{b2}^B\right)}}{e^{\left(q_{b1}^C - p_{b1}^C\right)} + e^{\left(q_{b2}^B - p_{b2}^B\right)} + e^{\left(\theta q_{e2}^B - p_{e2}^B\right)}} \tag{4–35}$$

$$\chi_{e2}^B = \frac{e^{\left(\theta q_{e2}^B - p_{e2}^B\right)}}{e^{\left(q_{b1}^C - p_{b1}^C\right)} + e^{\left(q_{b2}^B - p_{b2}^B\right)} + e^{\left(\theta q_{e2}^B - p_{e2}^B\right)}} \tag{4–36}$$

with $q_{b2}^B = 1/(2\alpha)$. Then, given q_{b1}^C and q_{e2}^B, each firm's profit maximization problem to set optimal prices is:

$$\Pi_1^C = \chi_{b1}^C \left[p_{b1}^C - \alpha\left(q_{b1}^C\right)^2\right] \tag{4–37}$$

$$\Pi_2^B = \chi_{b2}^B \left[p_{b2}^B - \frac{1}{4\alpha}\right] + \chi_{e2}^B \left[p_{e2}^B - \alpha\left(q_{e2}^B\right)^2\right] - \left[\frac{\gamma}{2} + \tau\right]\left(q_{e2}^B\right)^2 \tag{4–38}$$

The necessary conditions for optimum market prices charged by the two firms are:

$$\frac{\Pi_1^C}{\partial p_{b1}^C} = 0 \;\Rightarrow\; p_{b1}^C = \alpha\left(q_{b1}^C\right)^2 + \frac{1}{1-\chi_{b1}^C} \tag{4–39}$$

$$\frac{\Pi_2^B}{\partial p_{b2}^B} = 0 \;\Rightarrow\; p_{b2}^B - \frac{1}{4\alpha} = 1 + \chi_{e2}^B\left[p_{e2}^B - \alpha\left(q_{e2}^B\right)^2\right] + \chi_{b2}^B\left[p_{b2}^B - \frac{1}{4\alpha}\right] \tag{4–40}$$

$$\frac{\Pi^2}{\partial p_{e2}^B} = 0 \;\Rightarrow\; p_{e2}^B - \alpha\left(q_{e2}^B\right)^2 = 1 + \chi_{e2}^B\left[p_{e2}^B - \alpha\left(q_{e2}^B\right)^2\right] + \chi_{b2}^B\left[p_{b2}^B - \frac{1}{4\alpha}\right] \tag{4–41}$$

Equations (4–40) and (4–41) point out that the price markups for the brown and green products of Firm 2 are equal, based on which it is straightforward to derive

$$p_{b1}^{C} - \alpha\left(q_{b1}^{C}\right)^{2} = \frac{1}{\chi_{2}^{B}}, \tag{4–42}$$

$$p_{b2}^{B} - \frac{1}{4\alpha} = \frac{1}{\chi_{1}^{C}}, \text{ and} \tag{4–43}$$

$$p_{e2}^{B} - \alpha\left(q_{e2}^{B}\right)^{2} = \frac{1}{\chi_{1}^{C}}, \tag{4–44}$$

where $\chi_2^B = \chi_{b2}^B + \chi_{e2}^B$ and $\chi_1^C = \chi_{b1}^C$. Now suppose that $\Delta = \chi_1^C/\chi_2^B$, yielding to

$$\Delta = \left(\frac{e^{\left(q_{b1}^{C} - \alpha\left(q_{b1}^{C}\right)^{2}\right)}}{e^{\frac{1}{4\alpha}} + e^{\left(\theta q_{e2}^{B} - \alpha\left(q_{e2}^{B}\right)^{2}\right)}}\right) e^{\left(\frac{1}{\Delta} - \Delta\right)}. \tag{4–45}$$

Based on that the price functions provided in equations (4–42), (4–43) and (4–44) can be rewritten as follows:

$$p_{b1}^{C} = \alpha\left(q_{b1}^{C}\right)^{2} + 1 + \Delta \tag{4–46}$$

$$p_{b2}^{B} = \frac{1}{4\alpha} + 1 + \frac{1}{\Delta} \tag{4–47}$$

$$p_{e2}^{B} = \alpha\left(q_{e2}^{B}\right)^{2} + 1 + \frac{1}{\Delta} \tag{4–48}$$

Therefore, at the price equilibrium, the profit functions for each firm get equal to

$$\hat{\Pi}_{1}^{C} = \Delta, \tag{4–49}$$

$$\hat{\Pi}_{2}^{B} = \frac{1}{\Delta} - \left(\frac{\gamma}{2} + \tau\right)\left(q_{e2}^{B}\right)^{2}. \tag{4–50}$$

The necessary conditions for optimality for the profit functions in the first stage are

$$\frac{\partial \hat{\Pi}_{1}^{C}}{\partial q_{b1}^{C}} = \left(\frac{\Delta^{2}}{\Delta^{2} + \Delta + 1}\right)\left(1 - 2\alpha q_{b1}^{C}\right), \text{ and} \tag{4–51}$$

$$\frac{\partial \hat{\Pi}_{2}^{B}}{\partial q_{e2}^{B}} = \left(\frac{1}{\Delta^{2} + \Delta + 1}\right)\left(\frac{\theta - 2\alpha q_{e2}^{B}}{1 + e^{\left(\frac{1}{4\alpha} + \alpha\left(q_{e2}^{B}\right)^{2} - \theta q_{e2}^{B}\right)}}\right) - (\gamma + 2\tau) q_{e2}^{B}, \tag{4–52}$$

and setting these equal to 0, it is seen that

$$q_{b1}^{C} = \frac{1}{2\alpha}, \text{ and} \tag{4–53}$$

$$q_{e2}^{B} < \frac{\theta}{2\alpha}. \tag{4–54}$$

As in the previous case, it is easy to show that $0 < \Delta < 1$. Assuming that the FOCs are necessary and sufficient to identify an equilibrium, the following results hold for this setting. First, since $\Delta < 1$, the market share for Firm 2 is greater than that of Firm 1. This implies that it would be beneficial for a firm to pursue the Architect strategy, assuming the other firm is offering a brown product. Second, through numerical experiments (see Appendix F for numerical results for $\gamma = \$4$), it is observed that: (a) Firm 2's profits are greater than the profits of Firm 1; and (b) the difference in profits is remarkably insensitive to the marginal costs of advertising and product redesign (i.e., γ and τ, respectively). As expected it also turns out that Firm 2 incorporates a higher level of green quality in its new product as the marginal valuation of consumers θ goes up. In sum, this points to the fact that a firm in competition with another firm which simply offers a brown product reaps significant benefits (both in profits and market share) by adopting the Architect strategy.

4.4.3 Accentuate Strategy - Architect Strategy

Following a similar competition procedure proposed in Section 4.4.1 and Section 4.4.2, two competing firms are considered here - one accentuating its brown product and other complementing its brown product with a green alternative - and the MNL is used to describe the choice probabilities. In the first stage, without loss of generality, Firm 1 chooses the level of accentuated green quality q_{e1}^{A} while Firm 2 chooses the quality level of its green product q_{e2}^{B}. In the second stage, revitalized prices of the brown products p_{b1}^{A} and p_{b2}^{B}, and the price of the new green product p_{e2}^{B} are selected by firms. Given that all consumers always purchase one unit of their most preferred product in the marketplace, the market shares of the products are:

$$\chi_{b1}^{A} = \frac{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^{A}-p_{b1}^{A}\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^{A}-p_{b1}^{A}\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^{B}\right)}+e^{\left(\theta q_{e2}^{B}-p_{e2}^{B}\right)}} \tag{4–55}$$

$$\chi_{b2}^{B} = \frac{e^{\left(\frac{1}{2\alpha}-p_{b2}^{B}\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^{A}-p_{b1}^{A}\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^{B}\right)}+e^{\left(\theta q_{e2}^{B}-p_{e2}^{B}\right)}} \tag{4–56}$$

$$\chi_{e2}^{B} = \frac{e^{\left(\theta q_{e2}^{B}-p_{e2}^{B}\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^{A}-p_{b1}^{A}\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^{B}\right)}+e^{\left(\theta q_{e2}^{B}-p_{e2}^{B}\right)}} \tag{4–57}$$

Based on that each firm's profit maximization problem to set the optimal prices is:

$$\Pi_1^{A} = \chi_{b1}^{A}\left[p_{b1}^{A}-\frac{1}{4\alpha}\right]-\left[\frac{\gamma}{2}\right]\left(q_{e1}^{A}\right)^2 \tag{4–58}$$

$$\Pi_2^{B} = \chi_{b2}^{B}\left[p_{b2}^{B}-\frac{1}{4\alpha}\right]+\chi_{e2}^{B}\left[p_{e2}^{B}-\alpha\left(q_{e2}^{B}\right)^2\right]-\left[\frac{\gamma}{2}+\tau\right]\left(q_{e2}^{B}\right)^2 \tag{4–59}$$

Based on the necessary conditions for optimum market prices charged by the two firms, the price markups for the brown and green products of Firm 2 appear to be equal that yields to

$$p_{b1}^{A}-\frac{1}{4\alpha} = \frac{1}{\chi_2^{B}}, \tag{4–60}$$

$$p_{b2}^{B}-\frac{1}{4\alpha} = \frac{1}{\chi_1^{A}}, \tag{4–61}$$

$$p_{e2}^{B}-\alpha\left(q_{e2}^{B}\right)^2 = \frac{1}{\chi_1^{A}}, \tag{4–62}$$

where $\chi_2^B = \chi_{b2}^B + \chi_{e2}^B$ and $\chi_1^A = \chi_{b1}^A$. Now suppose $\Delta = \chi_1^A/\chi_2^B$ so that

$$\Delta = \frac{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^{A}-p_{b1}^{A}\right)}}{e^{\left(\frac{1}{2\alpha}-p_{b2}^{B}\right)}+e^{\left(\theta q_{e2}^{B}-p_{e2}^{B}\right)}}, \tag{4–63}$$

based on which the price functions can be rewritten as follows:

$$p_{b1}^{A} = \frac{1}{4\alpha}+1+\Delta \tag{4–64}$$

$$p_{b2}^{B} = \frac{1}{4\alpha}+1+\frac{1}{\Delta} \tag{4–65}$$

$$p_{e2}^{B} = \alpha\left(q_{e2}^{B}\right)^2+1+\frac{1}{\Delta} \tag{4–66}$$

Therefore, at the price equilibrium, the profit functions for each firm can be restated as

$$\hat{\Pi}_1^A = \Delta - \left[\frac{\gamma}{2}\right]\left(q_{e1}^A\right)^2, \tag{4–67}$$

$$\hat{\Pi}_2^B = \frac{1}{\Delta} - \left[\frac{\gamma}{2} + \tau\right]\left(q_{e2}^B\right)^2, \tag{4–68}$$

and the necessary conditions of optimality for each firm gets the following form:

$$\frac{\partial \hat{\Pi}_1^A}{\partial q_{e1}^A} = \left(\frac{\theta\Delta^2}{1+\Delta+\Delta^2}\right) - \gamma q_{e1}^A \tag{4–69}$$

$$\frac{\partial \hat{\Pi}_2^B}{\partial q_{e2}^B} = \left(\frac{1}{1+\Delta+\Delta^2}\right)\left[\frac{\theta - 2\alpha q_{e2}^B}{1+e^{\left(\frac{1}{4\alpha}+\alpha\left(q_{e2}^B\right)^2-\theta q_{e2}^B\right)}}\right] - (\gamma+2\tau)q_{e2}^B \tag{4–70}$$

Setting these equal to 0, it is easy to obtain

$$q_{e1}^A = \frac{\theta\Delta^2}{\gamma\left(1+\Delta+\Delta^2\right)}, \text{ and} \tag{4–71}$$

$$q_{e2}^B < \frac{\theta}{2\alpha}. \tag{4–72}$$

Similar to findings in Section 4.4.1 and Section 4.4.2, it is relatively straightforward to show that $0 < \Delta < 1$. Representing the ratio of the market share of Firm 1's accentuated brown product to the total market share of Firm 2's brown and green products, $\Delta < 1$ points out that a firm in the pursuit of commanding a larger market share is better off employing the Architect strategy, presuming that its competitor is implementing the Accentuate strategy. Even though the firm following the Architect strategy cannot avoid the losses in market share of its existing brown product, the new green product recoups the brown product's lost sales, helping the firm subsequently enjoy a success in total market share. The numerical analysis carried out for this competition scenario also shows that a firm choosing the Architect strategy in the presence of another firm choosing the Accentuate strategy stands to make higher profits (see Appendix G for numerical data and results). Notably, this gap between the profits does not noticeably narrow down or widen out with differing values of marginal advertising and product redesign costs.

In the following three sections, the duopoly environment where both firms compete under identical strategy choices is analyzed.

4.4.4 Current Setting - Current Setting

It is first proposed that two firms compete under the base scenario in which each firm offers a single brown product into the market. Then, the key decisions for both firms are the levels of brown quality (i.e., q_{b1}^C and q_{b2}^C), and the market prices for their brown products (i.e., p_{b1}^C and p_{b2}^C). Given that no-purchase option is no longer accommodated for consumers, the market shares of Firm 1 and Firm 2 are given respectively as follows:

$$\chi_{b1}^C = \frac{\Delta}{1+\Delta} \tag{4–73}$$

$$\chi_{b2}^C = \frac{1}{1+\Delta} \tag{4–74}$$

where $\Delta = e^{-\left(q_{b2}^C - q_{b1}^C\right)+\left(p_{b2}^C - p_{b1}^C\right)}$. Based on the market share functions, given q_{b1}^C and q_{b2}^C, each firm's profit maximization problem to set optimal prices is:

$$\Pi_1^C = \chi_{b1}^C \left[p_{b1}^C - \alpha\left(q_{b1}^C\right)^2\right] \tag{4–75}$$

$$\Pi_2^C = \chi_{b2}^C \left[p_{b2}^C - \alpha\left(q_{b2}^C\right)^2\right] \tag{4–76}$$

The necessary conditions for optimum market prices charged by the two firms are:

$$\frac{\partial \Pi_1^C}{\partial p_{b1}^C} = 0 \quad \Rightarrow \quad p_{b1}^C = \alpha\left(q_{b1}^C\right)^2 + 1 + \Delta \tag{4–77}$$

$$\frac{\partial \Pi_2^C}{\partial p_{b2}^C} = 0 \quad \Rightarrow \quad p_{b2}^C = \alpha\left(q_{b2}^C\right)^2 + 1 + \frac{1}{\Delta} \tag{4–78}$$

Evaluating the profit functions for each firm at the price equilibrium then yields:

$$\hat{\Pi}_1^C = \Delta \tag{4–79}$$

$$\hat{\Pi}_2^C = \Delta \tag{4–80}$$

In the first stage, the FOCs for each firm are:

$$\frac{\partial \hat{\Pi}_1^C}{\partial q_{b1}^C} = \Delta\left(-2\alpha q_{b1}^C + 1\right) \tag{4–81}$$

$$\frac{\partial \hat{\Pi}_2^C}{\partial q_{b2}^C} = \Delta\left(-2\alpha q_{b2}^C + 1\right) \tag{4–82}$$

Setting these equal to 0, it is obtained

$$q_{b1}^C = \frac{1}{2\alpha}, \tag{4–83}$$

$$q_{b2}^C = \frac{1}{2\alpha}. \tag{4–84}$$

Now it must be shown that the second-order derivative of profit functions $\hat{\Pi}_1^C$ ($\hat{\Pi}_2^C$) with respect to q_{b1}^C (q_{b2}^C) when $\partial\hat{\Pi}_1^C/\partial q_{b1}^C = 0$ ($\partial\hat{\Pi}_2^C/\partial q_{b2}^C = 0$) is negative. Following a similar procedure used for the derivation of the first-order conditions above, it is straightforward to show that

$$\frac{\partial^2 \hat{\Pi}_1^C}{\partial {q_{b1}^C}^2} = -2\alpha\left(\frac{\Delta^2}{\Delta^2+\Delta+1}\right) < 0, \tag{4–85}$$

$$\frac{\partial^2 \hat{\Pi}_2^C}{\partial {q_{b2}^C}^2} = -2\alpha\left(\frac{\Delta^2}{\Delta^2+\Delta+1}\right) < 0. \tag{4–86}$$

Therefore, the profit functions $\hat{\Pi}_1^C$ and $\hat{\Pi}_2^C$ are quasi-concave, and $q_{b1}^C = q_{b2}^C = 1/(2\alpha)$ means that equilibrium prices in the second stage are equal with a value of $2 + 1/(4\alpha)$.

Comparison of the results derived for the monopoly and duopoly environments under the base scenario has the following implications. First, no matter what the outside alternative is (another profit-maximizing firm or a no-purchase option), the firm retains offering his brown product at the same quality level given by $1/(2\alpha)$. This also implies that in a duopolistic market both firms select the same quality which is the highest possible one. Secondly, the optimal quality in both monopoly and duopoly settings is a decreasing function of marginal cost of production. Finally, it is observed that when the unit cost of production is increased by a fixed amount - given that the marginal cost of quality is unaffected - quality of the brown product remains unchanged, but the cost increase is passed on to consumers.

4.4.5 Accentuate Strategy - Accentuate Strategy

An alternative duopoly scenario is considered here whereby two firms - currently offering brown products, of quality $1/(2\alpha)$ - compete under the Accentuate strategy. The equilibrium concept is similar as in the preceding sections - that is, the objective is to find equilibria to the two-stage game where the levels of green quality that should be accentuated (i.e., q_{e1}^A and q_{e2}^A) are chosen at the first stage and prices of the accentuated brown products (i.e., p_{b1}^A and p_{b2}^A) at the second. In this competition environment, the market shares of Firm 1 and Firm 2 are given respectively as follows:

$$\chi_{b1}^A = \frac{\Delta}{1+\Delta} \tag{4–87}$$

$$\chi_{b2}^A = \frac{1}{1+\Delta} \tag{4–88}$$

$$\tag{4–89}$$

where $\Delta = e^{-\theta\left(q_{e2}^A - q_{e1}^A\right)+\left(p_{b2}^A - p_{b1}^A\right)}$. Then, given q_{e1}^A and q_{e2}^A, each firm's profit maximization problem to set optimal prices is:

$$\Pi_1^A = \chi_{b1}^A \left[p_{b1}^A - \frac{1}{4\alpha}\right] - \left[\frac{\gamma}{2}\right]\left(q_{e1}^A\right)^2 \tag{4–90}$$

$$\Pi_2^A = \chi_{b2}^A \left[p_{b2}^A - \frac{1}{4\alpha}\right] - \left[\frac{\gamma}{2}\right]\left(q_{e2}^A\right)^2 \tag{4–91}$$

The necessary conditions for optimum market prices charged by the two firms are:

$$\frac{\partial \Pi_1^A}{\partial p_{b1}^A} = 0 \quad \Rightarrow \quad p_{b1}^A = \frac{1}{4\alpha} + 1 + \Delta \tag{4–92}$$

$$\frac{\partial \Pi_2^A}{\partial p_{b2}^A} = 0 \quad \Rightarrow \quad p_{b2}^A = \frac{1}{4\alpha} + 1 + \frac{1}{\Delta} \tag{4–93}$$

so that $p_{b2}^A - p_{b1}^A = \frac{1}{\Delta} - \Delta$. Then, at the price equilibrium, the profit functions for each firm can be restated as follows:

$$\hat{\Pi}_1^A = \Delta - \left[\frac{\gamma}{2}\right]\left(q_{e1}^A\right)^2 \tag{4–94}$$

$$\hat{\Pi}_2^A = \frac{1}{\Delta} - \left[\frac{\gamma}{2}\right]\left(q_{e2}^A\right)^2 \tag{4–95}$$

In the first stage, the FOCs for each firm are:

$$\frac{\partial \hat{\Pi}_1^A}{\partial q_{e1}^A} = \left(\frac{\theta\Delta^2}{1+\Delta+\Delta^2}\right) - \gamma q_{e1}^A \tag{4–96}$$

$$\frac{\partial \hat{\Pi}_2^A}{\partial q_{e2}^A} = \left(\frac{\theta}{1+\Delta+\Delta^2}\right) - \gamma q_{e2}^A \tag{4–97}$$

Setting these equal to 0, it is obtained

$$q_{e1}^A = \frac{\theta\Delta^2}{\gamma\left(1+\Delta+\Delta^2\right)}, \tag{4–98}$$

$$q_{e2}^A = \frac{\theta}{\gamma\left(1+\Delta+\Delta^2\right)}. \tag{4–99}$$

Taking the difference of these two equations yields

$$q_{e1}^A - q_{e2}^A = \left(\frac{\theta}{\gamma}\right)\left[\frac{\Delta^2-1}{1+\Delta+\Delta^2}\right]. \tag{4–100}$$

Besides, provided that $p_{b2}^A - p_{b1}^A = \frac{1}{\Delta} - \Delta$, the expression of Δ yields an implicit solution

$$\Delta = e^{-\theta\left(q_{e2}^A - q_{e1}^A\right) + \frac{1}{\Delta} - \Delta}. \tag{4–101}$$

Now combining equation (4–100) with equation (4–101) leads to

$$\Delta = e^{\left[\frac{\theta^2}{\gamma}\left(\frac{\Delta^2-1}{1+\Delta+\Delta^2}\right) - \left(\frac{\Delta^2-1}{\Delta}\right)\right]}, \tag{4–102}$$

which clearly has a candidate solution $\Delta = 1$. Based on this solution, from equation (4–98) and equation (4–99), the candidate equilibrium solutions are ${q_{e1}^A}^* = {q_{e2}^A}^* = \theta/(3\gamma)$ with the corresponding prices ${p_{b1}^A}^* = {p_{b2}^A}^* = 2 + 1/(4\alpha)$ according to equation (4–92) and equation (4–93).

Now it must be shown that ${q_{e1}^{A}}^{*}$ (${q_{e2}^{A}}^{*}$) maximizes $\hat{\Pi}_1^A$ ($\hat{\Pi}_2^A$). Without loss of generality, consider Firm 1. The second order derivative of $\hat{\Pi}_1^A$ with respect to q_{e1}^A is given as

$$\frac{\partial^2 \hat{\Pi}_1^A}{\partial {q_{e1}^A}^2} = \theta^2 \left[\frac{\Delta^3(\Delta+2)}{(1+\Delta+\Delta^2)^3}\right] - \gamma. \tag{4–103}$$

At the candidate equilibrium where $\Delta = 1$, this expression gets equal to

$$\frac{\partial^2 \hat{\Pi}_1^A}{\partial {q_{e1}^A}^2} = \frac{\theta^2}{9} - \gamma, \tag{4–104}$$

which is negative as long as $\theta < 3\sqrt{\gamma}$. In other words, when this inequality is satisfied, there is a symmetric equilibrium of the first stage game with ${q_{e1}^A}^* = {q_{e2}^A}^* = \theta/(3\gamma)$.

4.4.6 Architect Strategy - Architect Strategy

This scenario focuses on a duopoly competition under Architect strategy where each firm has the option of altering the price of its existing product at the time of introducing a new green product into the market, whereas its quality is fixed at $1/(2\alpha)$. The market share side is similar as in the duopoly market structures studied in the preceding sections and so the market shares of the products are given as follows:

$$\chi_{b1}^B = \frac{e^{\left(\frac{1}{2\alpha}-p_{b1}^B\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^B-p_{b1}^B\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^B\right)}+e^{\left(\theta q_{e1}^B-p_{e1}^B\right)}+e^{\left(\theta q_{e2}^B-p_{e2}^B\right)}} \tag{4–105}$$

$$\chi_{e1}^B = \frac{e^{\left(\theta q_{e1}^B-p_{e1}^B\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^B-p_{b1}^B\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^B\right)}+e^{\left(\theta q_{e1}^B-p_{e1}^B\right)}+e^{\left(\theta q_{e2}^B-p_{e2}^B\right)}} \tag{4–106}$$

$$\chi_{b2}^B = \frac{e^{\left(\frac{1}{2\alpha}-p_{b2}^B\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^B-p_{b1}^B\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^B\right)}+e^{\left(\theta q_{e1}^B-p_{e1}^B\right)}+e^{\left(\theta q_{e2}^B-p_{e2}^B\right)}} \tag{4–107}$$

$$\chi_{e2}^B = \frac{e^{\left(\theta q_{e2}^B-p_{e2}^B\right)}}{e^{\left(\frac{1}{2\alpha}+\theta q_{e1}^B-p_{b1}^B\right)}+e^{\left(\frac{1}{2\alpha}-p_{b2}^B\right)}+e^{\left(\theta q_{e1}^B-p_{e1}^B\right)}+e^{\left(\theta q_{e2}^B-p_{e2}^B\right)}} \tag{4–108}$$

Based on that each firm's profit maximization problem to set the optimal prices is:

$$\Pi_1^B = \chi_{b1}^B\left[p_{b1}^B - \frac{1}{4\alpha}\right] + \chi_{e1}^B\left[p_{e1}^B - \alpha\left(q_{e1}^B\right)^2\right] - \left[\frac{\gamma}{2}+\tau\right]\left(q_{e1}^B\right)^2 \tag{4–109}$$

$$\Pi_2^B = \chi_{b2}^B\left[p_{b2}^B - \frac{1}{4\alpha}\right] + \chi_{e2}^B\left[p_{e2}^B - \alpha\left(q_{e2}^B\right)^2\right] - \left[\frac{\gamma}{2}+\tau\right]\left(q_{e2}^B\right)^2 \tag{4–110}$$

Based on the necessary conditions for optimum market prices charged by the two firms, the price markups for the brown and green products of each firm appear to be equal that yields to

$$
\begin{aligned}
p_{b1}^{B} - \frac{1}{4\alpha} &= \frac{1}{\chi_2^B}, && (4\text{–}111)\\
p_{e1}^{B} - \alpha\left(q_{e1}^{B}\right)^2 &= \frac{1}{\chi_2^B}, && (4\text{–}112)\\
p_{b2}^{B} - \frac{1}{4\alpha} &= \frac{1}{\chi_1^B}, && (4\text{–}113)\\
p_{e2}^{B} - \alpha\left(q_{e2}^{B}\right)^2 &= \frac{1}{\chi_1^B}, && (4\text{–}114)
\end{aligned}
$$

where $\chi_1^B = \chi_{b1}^B + \chi_{e1}^B$ and $\chi_2^B = \chi_{b2}^B + \chi_{e2}^B$. Now suppose $\Delta = \chi_1^B/\chi_2^B$ so that

$$
\Delta = \frac{e^{\left(\frac{1}{2\alpha} - p_{b1}^B\right)} + e^{\left(\theta q_{e1}^B - p_{e1}^B\right)}}{e^{\left(\frac{1}{2\alpha} - p_{b2}^B\right)} + e^{\left(\theta q_{e2}^B - p_{e2}^B\right)}}, \qquad (4\text{–}115)
$$

based on which the price functions can be rewritten as follows:

$$
\begin{aligned}
p_{b1}^{B} &= \frac{1}{4\alpha} + 1 + \Delta && (4\text{–}116)\\
p_{e1}^{B} &= \alpha\left(q_{e1}^{B}\right)^2 + 1 + \Delta && (4\text{–}117)\\
p_{b2}^{B} &= \frac{1}{4\alpha} + 1 + \frac{1}{\Delta} && (4\text{–}118)\\
p_{e2}^{B} &= \alpha\left(q_{e2}^{B}\right)^2 + 1 + \frac{1}{\Delta} && (4\text{–}119)
\end{aligned}
$$

Therefore, at the price equilibrium, the profit functions for each firm can be restated as

$$
\begin{aligned}
\hat{\Pi}_1^B &= \Delta - \left[\frac{\gamma}{2} + \tau\right]\left(q_{e1}^B\right)^2, && (4\text{–}120)\\
\hat{\Pi}_2^B &= \frac{1}{\Delta} - \left[\frac{\gamma}{2} + \tau\right]\left(q_{e2}^B\right)^2, && (4\text{–}121)
\end{aligned}
$$

and the necessary conditions of optimality for each firm gets the following form:

$$
\begin{aligned}
\frac{\partial \hat{\Pi}_1^B}{\partial q_{e1}^B} &= \left(\frac{\Delta}{1+\Delta+\Delta^2}\right)\left[\frac{\theta - 2\alpha q_{e1}^B}{1 + e^{\left(\frac{1}{4\alpha} + \alpha\left(q_{e1}^B\right)^2 - \theta q_{e1}^B\right)}}\right] e^{\left(\frac{1}{\Delta} - \Delta\right)} - (\gamma + 2\tau) q_{e1}^B && (4\text{–}122)\\
\frac{\partial \hat{\Pi}_2^B}{\partial q_{e2}^B} &= \left(\frac{1}{1+\Delta+\Delta^2}\right)\left[\frac{\theta - 2\alpha q_{e2}^B}{1 + e^{\left(\frac{1}{4\alpha} + \alpha\left(q_{e2}^B\right)^2 - \theta q_{e2}^B\right)}}\right] - (\gamma + 2\tau) q_{e2}^B && (4\text{–}123)
\end{aligned}
$$

Setting these equal to 0 and taking the ratio yields

$$\mathcal{S}\left(q_{e1}^{B}, q_{e2}^{B}\right) \equiv \Delta e^{\left(\frac{1}{\Delta}-\Delta\right)}\left(\frac{\theta-2\alpha q_{e1}^{B}}{\theta-2\alpha q_{e2}^{B}}\right)\left[\frac{e^{\theta q_{e1}^{B}-\alpha q_{e1}^{B\,2}}}{e^{\theta q_{e2}^{B}-\alpha q_{e2}^{B\,2}}}\right]-\frac{q_{e1}^{B}}{q_{e2}^{B}}=0 \qquad (4–124)$$

as the equation describing putative equilibria. Note that there exists a q such that $q_{e1}^{B}=q_{e2}^{B}=q$ and $\Delta=1$ as a feasible solution for $\mathcal{S}\left(q_{e1}^{B}, q_{e2}^{B}\right)$, and it is obtained by the implicit solution of the following equation:

$$\mathcal{H}(q) \equiv \left[\frac{\theta}{3(\gamma+2\tau)}\right]\left(\frac{1}{q}\right)-\left[\frac{4\alpha}{3\gamma+6\tau}+1\right]-e^{\left(\frac{1}{4\alpha}+\alpha q^{2}-\theta q\right)}=0 \qquad (4–125)$$

On the basis of the analyses of all competition scenarios studied in Section 4.4, the payoff matrix representing the corresponding profits of both firms for each possible combination of strategies can be formulated as follows:

		Firm 2: Base	Firm 2: Accentuate	Firm 2: Architect
Firm 1	Base	$\hat{\Pi}_1^C$, $\hat{\Pi}_2^C$	$\hat{\Pi}_1^C$, $\hat{\Pi}_2^A$	$\hat{\Pi}_1^C$, $\hat{\Pi}_2^B$
	Accentuate	$\hat{\Pi}_1^A$, $\hat{\Pi}_2^C$	$\hat{\Pi}_1^A$, $\hat{\Pi}_2^A$	$\hat{\Pi}_1^A$, $\hat{\Pi}_2^B$
	Architect	$\hat{\Pi}_1^B$, $\hat{\Pi}_2^C$	$\hat{\Pi}_1^B$, $\hat{\Pi}_2^A$	$\hat{\Pi}_1^B$, $\hat{\Pi}_2^B$

Structuring as a bargaining game of alternating strategies (i.e., Base, Accentuate and Architect) that can be implemented by two firms, a subgame perfect Nash equilibrium of this game can be characterized under some additional assumptions to identify the optimal strategy pair in a competitive green landscape.

4.5 Summary

The increasing consumer demand for green products is creating opportunities for companies to promote the greenness of their current offerings and introduce profitable new greener products. To the extent that these companies can meet or exceed these evolving consumer preferences, they will enhance their ability to increase their market share and profitability. One of the key issues in this context is how a firm should choose the right green product development strategy. Recent anecdotal/case study has indicated that there exists three broad strategies that companies can use to align their green goals with their capabilities: (a) marketing the green attributes inherent in their existing product (i.e., Accentuate strategy); (b) introducing a green product developed by the firm (i.e., Architect strategy); or (c) taking over a firm which offers green products (i.e., Acquire strategy). Based on the case study evidence, Unruh and Ettenson (2010) hypothesize that the best strategy choice is determined by the two dimensions: green attributes in the existing product lines and green process capabilities. However, this framework is incomplete for two reasons. First, it offers little or no guidelines on strategy choice for a firm which has an existing brown product offering with greenable attributes as well as substantial green product development capabilities. In fact, in this setting the firm's choice between the Accentuate and Architect strategies needs to be evaluated. Second, the perspective in this chapter is that there are other key drivers (in addition to green product attributes and green process capability) which need to be integrated in making the strategy choice.

In order to address these concerns, this chapter provides insights into the strategy choice between the Accentuate and Architect strategies using a stylized approach which incorporates consumer preferences for green quality, strategy specific supply side effects, and environmental mandates. From a theoretical perspective, note that this is one of the first studies which has examined alternative green product introduction strategies, and this analysis leads to a structural characterization of the optimal green quality and pricing decisions under each strategy choice, and an identification of the critical factors that drive the best strategy choice not only in a monopolist setting but also under competition.

The key managerial insights of this chapter are as follows. If regulatory constraints can be easily achieved (or are not imposed), then a company that is recognized for its brown product in the marketplace stands to benefit from integrating environmental friendliness into its product design. No matter what green product introduction strategy is chosen and implemented, incorporating environmental good into its product offering strategy helps strengthen the firm's market share while simultaneously providing bottom-line benefits. Of course, there is significant effort required to either reposition and advertise its existing brown product as better for the environment under the Accentuate strategy or promote a new green product under the Architect strategy. Another result worth noting is that regardless of whether the firm decides on either promoting the environmental performance of its existing brown product or introducing a new green product, it increases its market share and profits and hence, establishes a competitive advantage over a firm holding onto its existing brown product and existing marketing strategy. Finally, it is observed that strict environmental regulations drive up the prices of a firm's product offerings and could hinder the profitability of each green strategy choice.

Table 4-1. Comparison of Current and Accentuate strategies when $\gamma = \$4$

θ	Δ	q_{e2}^{A}	$\hat{\Pi}_1^C$	$\hat{\Pi}_2^A$
0.20	0.999	0.017	0.999	1.001
0.40	0.996	0.035	0.996	1.002
0.60	0.990	0.051	0.990	1.005
0.80	0.982	0.068	0.982	1.009
1.00	0.972	0.086	0.972	1.014

CHAPTER 5
GREEN, GREENER OR BROWN: CHOOSING THE RIGHT COLOR OF THE PRODUCT

5.1 Overview

The word “green” has entered the agenda in many companies today, and Klenier (1991) brings into focus three important questions that any company’s green agenda should include: (1) What green products should a company bring to the market, and what materials should it include in them?, (2) How should a company align its environmental actions with public perceptions?, and (3) How can a company engage in environmental protection at the source, rather than capturing or filtering pollutants downstream? Thus, a firm’s decision of how to go green is mainly driven by deciding what type of a green product to offer and what features to incorporate into this product, as well as understanding the environmentally conscious consumer market segments. Related to this point, Hopkins (2010) points out that a firm recognized for its brown offerings can mould green consumers’ perceptions about its product either by adding green features into its existing product or by coming up with a radically different design that is unabashedly better for the environment. These observations motivate the focus of this chapter. The intent here is to analyze two alternative strategies a firm with an existing brown product can choose and implement for integrating environmental benefits into its product design, and help brand executives at consumer product manufacturers to understand these strategies needed to find a profitable path to effectively addressing the changing needs of today’s consumers with a heightened environmental consciousness. This chapter fundamentally distinguishes from Chapter 4 in how consumer market is characterized such that the modeling framework proposed here incorporates two important characteristics of green marketplace. First, as described in detail in Chapter 1, in today’s marketplace there are many shades of green consumers, each having different attitudes and values that lead them to view particular offerings differently. Purchasing behavior varies significantly across these consumers, suggesting that not all products are affected equally by consumers' environmental concerns. This necessitates a clever segmentation scheme - rather then dividing whole consumer market into two distinct camps as Browns and Greens - for the firms to help them create a sensible road map of how to choose a market-facing green product strategy that works. Second, green products can even earn consideration from consumers that demonstrate the least environmental responsibility of all the segments. Likewise, even though they line up their shopping choices with their green values and express their environmental concerns in products they buy, even the most environmentalist consumers are motivated by universal needs and this translates into purchasing strategies with implications for the way greener products are designed. To summarize, consumers reach differently to green appeals and an opportunity exists for company managers to practice selling different products with different appeals to different segments.

The remainder of this chapter is organized as follows. Section 5.2 describes the modeling framework that involves the description of alternative green product development strategies and green consumer market, and this is followed by the model analysis in Section 5.3. In Section 5.4, the economic and environmental consequences of each strategy choice and drivers/obstacles of implementing each strategy are discussed, and Section 5.5 contains concluding remarks.

5.2 Model Preliminaries

The focus here is on a profit-maximizing monopolist firm that currently offers a "brown" product to a consumer market divided into three camps by customers' environmental attitudes and shopping behaviors, and that rethinks the ways how its product can be repositioned to appropriate the full possible value these customers' shifting green shopping habits will relinquish. In response to changing patterns in consumers' shopping behavior, the firm can nimbly fine-tune or radically adjust its product through following one of three ways: (a) realigning the prevailing brown product without addressing environmental concerns; (b) greening up the existing product by adding “green” features; or (c) replacing the current “brown” product with a new “green” product. These three choices are referred to as Greening Off, Greening Up and Greening Out strategies, respectively, onwards. In what follows, the green consumer market and how it is segmented into different shades of green are briefly described, and it is followed by the delineation of the cost structure of each strategy.

5.2.1 Green Consumer Segments

As noted earlier, consumers are increasingly factoring green sentiments into their shopping behaviors, and the incidence of green purchasing is so prevalent nowadays. Not every shopper responds to green products in the same way, though. That motivates firms to segment consumers by their shopping behavior and commitment to green in order to zero in on their most appropriate target customers. One such segmentation is provided by GfK Roper Public Affairs & Media as presented in Chapter 1. Recall that according to their 2002 public opinion survey on environmental issues, the vast majority of today’s consumers can be classified as some shade of green, signifying their involvement in green purchasing and environmental values, as follows:

- *True Blue Greens*: This 10% of the U.S. population are the most environmentally conscious and holistically originated consumers. They believe that individual actions can make a difference in solving environmental problems and are most likely to walk the green talk. Politically and socially active, they regularly boycott products made by companies that are careless toward the environment, rally support for environmental and social causes, and dedicate time and energy to influence others to do the same.

- *Greenback Greens*: About one in twenty consumers in the U.S. falls into the Greenback Greens segment. Greenback Greens see themselves as committed to sustainability, but in reality, they are not as politically active and as dedicated to green purchasing or behaviors as their True Blue cousins. Nevertheless, they are so named because of their willingness to pay a premium for environmentally friendly products or forego certain conveniences to ensure a cleaner environment.

- *Sprouts*: Sprouts, representing the one-third of the U.S. population, are also named as environmental “fence-sitters”. They show middling levels of concern about environmental problems. Even though they are inclined to adjust their shopping behaviors, they are not utterly resolute about which side of the environmental fence they are on, and so capable of going either way. With more and careful education, they are often the source for new Greenbacks and True-Blues.

- *Grousers*: Grousers, representing 15% of the U.S. population, are uninvolved in environmental issues. They are cynical about their ability to protect the environment, and believe that responsibility actually belongs to the government and large corporations. True to their name, Grousers complain that green products cost too much and do not perform as effectively as their brown counterparts or that they are too busy to shop green.
- *Basic Browns*: 37% of the U.S. population is classified as Basic Browns. In contrast to True-Blues and Greenbacks, Basic Browns are essentially unconcerned about the environment. They do not care about the environmental issues and they are convinced that buying green products cannot make a difference in helping to protect and improve the environment.

These figures point out that environmental attitudes vary across the shades such that the deeper the shade of green is, the more likely corresponding consumers are to purchase green products. The deepest are the True Blue Greens and Greenback Greens that qualify as the true environmentalists. In the middle are the Sprouts, referred as the “swing” group that can go either way on any environmental issue, followed by non-environmentalists in nature, namely Grousers and Basic Browns. It is important to note that even though green products do not appeal to every single consumer in the market yet, the number of consumers touting a true blue or greenback perspective increases over time, and 15% to 48% of the entire consumer market could be attracted to green products, depending on perceived benefits associated with green products. True Blues and Greenbacks are, in addition, highly desirable target shoppers, representing high value segments that are less price sensitive, more likely to repurchase products and that tend to stick with a green product once they have adopted it. Their potential to exert increasing pressure on their peers - particularly on the Sprouts, the second largest of the five groups - also underscores a large opportunity for company managers who can win over these influential True-Blues and Greenbacks.

Prior to marketing and providing greener products, understanding the effects of green considerations on shopping behavior of the target consumer market is very essential for a firm to determine whether greenness is a key attribute influencing shopping decisions and how it should be incorporated into the product design. Every green consumer segment has distinctive tastes and shopping behaviors - they are not indifferent to the value offered by green products. In order to respond consumers' varying degrees of green shopping behaviors, here the target consumer market is segmented into three shades of green: Greens, Fence-Sitters and Browns. The Greens segment (G) consists of True Blues and Greenbacks; the Fence-Sitters segment (F) is comprised of Sprouts; and finally, Grousers and Basic Browns constitute the Browns segment (B). It is assumed that the total number of consumers in the market is M, and the proportion of consumers falling into the Greens, Fence-Sitters and Browns segments are denoted by r_G, r_F and r_B, respectively, with $r_G + r_F + r_B = 1$. Based on differing purchasing behaviors of green consumer segments, the next section describes the individual purchase decision of a consumer in each market segment.

5.2.2 Consumers' Valuation of the Product

Awareness of environmental issues continues to grow and its influence on consumer behavior and product choices continues to evolve. Today's consumers have higher expectations for the products they buy and environmental attributes emerge as a new dimension of product quality. Therefore, it can be posited that a product's design attributes can be classified into two distinct dimensions: traditional and environmental attributes - so that designing a product involves setting each attribute level. This can be interpreted as the aggregation of multiple attributes into two major dimensions. An environmental attribute, for instance, may represent a set of product characteristics that are more environmentally sustainable such as recycled content, energy- and fuel-efficiency, and non-toxicity, while a traditional attribute can be considered as a composite measure of safety, availability and style. Given the assumption that both attributes behave like "qualities" (i.e., consumers always prefer more of attributes than less), from here onwards they will be called as traditional and environmental qualities, denoted by q_t and q_e, respectively.

Consumers in a vertically differentiated market agree on the ranking of product quality, yet they differ in their willingness to pay for quality. As described in Section 5.2.1, the consumer market here is comprised of three distinct market segments, namely Greens, Fence-Sitters and Browns, with differing willingness to pay for a given product[1] . The utility that a consumer in Browns segment derives from a product (q_t, q_e) is given by $U_B = v_t q_t + \theta_B v_e q_e - p$, where v_t (v_e) is the marginal willingness to pay or marginal valuation on traditional (environmental) quality, p is the price of the product, and $\theta_B \in (0, 1)$ represents Browns' responsiveness to environmental benefits integrated into the product design[2] . Note that the value of θ_B relies on which - and to what extent - product-related environmental issues concern Browns segment consumers. In practice, green appeals are not likely to attract Browns segment consumers. On the other hand, environmental benefits, such as energy-efficiency and water-efficiency, can help cost-conscious Browns segment consumers save money on energy and water bills over the long term, and so can be a powerful motivator[3] . Similarly, a Browns segment consumer, for example, might own a hybrid because it is more fuel-efficient and so he can eventually save money (beyond the purchase premium), or he can make fewer trips to the filling station. Such genuine value-added benefits of cost savings, convenience,

[1] The market is segmented such that consumers within a segment are homogenous in the amount of utility they derive from the purchase of a product.

[2] Following the established literature, the notion of consumer valuation is used to describe the utility derived by a consumer, and consumer's valuation of a product is assumed to be a linear function of its quality levels.

[3] For instance, Energy Star® rated washers use 30% less energy and at least 50% less water than do traditional washers, while Energy Star® refrigerators use at least 15% less energy than do standard models. Likewise, CFL bulbs use about 75% less energy than standard incandescent bulbs and lasts up 10 times longer.

and increased health and safety can resonate with Browns segment consumer values and propel them for green products while at the same time promoting environmental benefits - a dual feature leading to a higher θ_B value. In contrast, because they are not tuned in or turned on the environment, Browns are most likely to be indifferent to environmental considerations such as how a product is manufactured, where raw materials are procured or whether a product and its packaging can be safely disposed of - keeping θ_B at lower values close to 0.

In like vein, given a product (q_t, q_e) offered at price p, a Greens segment consumer's associated utility is given by $U_G = \theta_G v_t q_t + v_e q_e - p$, where $\theta_G \in (0, 1)$ represents the extent of Greens' approval of the product's non-green attributes. It can be argued that even the greenest consumers no longer buy green products just to protect the environment and many green products have failed because of companies' focus on their products' greenness over the broader expectations of green consumers[4] . Roper's 2002 public opinion survey finds that one of the top reasons green consumers do not buy a green product is that this product may require sacrifices in user safety. Then, it can be underlined that even though altruistically-driven or deep-green consumers will buy green products regardless of their ease of accessibility or style, they must be convinced of the particular "non-green" benefits of these products (e.g., safety). This in turn showcases that Greens segment consumers, seeking out products that synchronize with their discerning environmental standards, favor the product based on its green benefits, but they also drive positive values from the non-green attributes of this product, captured by positive values of θ_G in this model. From here onwards, for the sake of clarity, Browns

[4] See Levitt (1960) where the common pitfall of companies' tunnel vision that focuses on managing products (i.e., product features and functions) instead of meeting green customers' needs (i.e., adapting to consumer expectations and desires) is characterized.

and Greens segments are assumed to be symmetric with respect to their calculation of a product's value, meaning that $\theta_B = \theta_G = \theta$[5] .

Considering the middling segment Fence-Sitters, recall that Sprouts is a "key" group, since they have environmental attitudes that can cut both ways and so are capable of going either way, while Browns and Greens segments are more static and less likely to exhibit movement over time. Sprouts have ambivalent attitudes towards buying green products, and Ginsberg and Bloom (2004) state that they "can be persuaded to buy green if appealed appropriately." Therefore, the utility derived by a consumer in the Fence-Sitters segment from purchasing a product of quality levels (q_t, q_e) can be expressed as $U_F = v_t q_t + v_e q_e - p$. The Fence-Sitter segment consumers' utility function confirms that shoppers positioned on the fence use traditional and environmental attributes as part of their personal formula for recognizing the value of a product, and fully integrate two distinct qualities into their actual buying decisions. The utility function of the Greens segment shows that these consumers prioritize environment above other product features and make their purchasing decisions solely based on environmental considerations in product design whenever possible. On the contrary, according to their utility function, the Brown segment consumers reject environmental considerations, and look for and buy products that meet their non-green purchasing criteria - and this non-green criteria might in fact be an environmental benefit such as the energy-efficiency sought by cost-conscious consumers.

5.2.3 Cost Structure

On the supply side, the monopolist firm intends to serve all the customers in targeted market segment(s) with either a single-attribute product (i.e., a brown product characterized solely by a traditional attribute q_t or a green product represented solely

[5] Incorporating this assumption in the model simplifies the analysis but does not change the qualitative nature of the results.

by an environmental attribute q_e) or a two-attribute product (i.e., a greened-up product composed of both types of attributes). Based on the argument put forward by Moorthy (1984) that production cost increases at a faster rate than the consumers' willingness to pay, the cost of supplying a product - regardless of whether it is a brown, green or greened-up product - increases quadratically with its quality level(s)[6] . More specifically, it is assumed that the unit cost of supplying a brown product (q_t) and a green product (q_e) are given by $c_t q_t^2$ and $c_e q_e^2$, respectively, where c_t and c_e are positive cost coefficients[7] . Similarly, the unit cost of production for the greened-up product (q_t, q_e) is reflected by cost function $c_u(q_t + q_e)^2$, where $c_u > 0$. Note that cost coefficients c_t, c_e and c_u here reflect the differences in cost of producing a product across different quality types.

In addition to the per-unit variable production costs, the total cost of a green product and a greened-up product comprises another strategy specific component. In implementing the Greening Out strategy, the firm is destined to incur upfront costs from introducing a new green product into the market for process R&D, market research and other relevant expenses. Being consistent with the previous literature on new product development (e.g., Chen (2001)), the presumed sunk costs of developing and launching the green product is represented by a constant $N > 0$. Under the strategy of Greening Up, the firm improves the environmental quality of its existing brown product by designing bad materials out of the product or replacing its bad materials with better ones. Such R&D related efforts of the firm directly translates into a fixed cost of product redesign (e.g., cost of developing renewable packaging material), which is assumed

[6] Given the assumption that both attributes behave like qualities, it is reasonable to further assume that the cost of offering an attribute increases with the attribute level.

[7] Note that this functional form for the per unit production cost of a product has also been used in Moorthy (1984) and Chen (2001).

to be convex and strictly increasing in the environmental quality q_e designed into the existing brown product and given by Fq_e^2 with $F > 0$[8] .

Based on this articulation of product repositioning strategies, relevant market segments, the individual consumer purchasing decision in each segment and cost structure of each strategy choice, next section characterizes the key product development and pricing decisions for the monopolist.

5.3 Analysis: Model Formulation

5.3.1 Greening Off Strategy

Under this strategy, a firm that currently offers a single brown product (q_t, p) *stays* on the traditional track by holding onto its existing brown product and seeking to balance consumers' needs for performance and affordability without any concern for environmental considerations. The firm's potential shopper base is made up of Browns, Fence-Sitters and Greens segment consumers, because its brown offering can make its way to these consumers' shopping lists based solely on its traditional attributes. Recall from Section 5.2.2 that a brown product, of quality q_t, delivers a value of $v_t q_t$ to Browns and Fence-Sitters, while Greens value the same product differently at $\theta v_t q_t$ with $0 \leq \theta \leq 1$. Looking to cash in on its existing brown product, the firm can then take advantage of such a segmented consumer market structure - as it makes extracting value and moderating demand possible - by using one of two different pricing options:

i. The firm can target its existing brown product specifically at only Browns and Fence-Sitters consumers by setting a selling price equivalent to these two segments' willingness to pay for a unit of traditional quality (i.e., $v_t q_t$) - a move that enables the firm to extract all consumer surplus from Browns and Fence-Sitters segments. Nonetheless, asking Greens to accept a product without any environmental benefits at fairly high prices is likely to keep these

[8] The quadratic structure of product redesign cost is an approximation of a general convex cost function widely observed in practice, and it has been commonly employed in the research literature (e.g., Lacourbe et al. (2009).

customers away from purchasing the product as the valuation they place on the brown product will fall below its selling price (i.e., $\theta v_t q_t < v_t q_t$, unless θ is equal to 1), resulting in a drop-off, of value Mr_G, in the addressable market size. Therefore, the monopolist firm faces a profit maximization problem, of the form $\Pi_1^i = M(r_B + r_F)(v_t q_t - c_t q_t^2)$ with $q_t \geq 0$, based on which the optimal values of traditional quality and profit are obtained as follows:

$$q_t^* = \frac{v_t}{2c_t} \tag{5–1}$$

$$\Pi_1^{i\,*} = \frac{M(r_B + r_F)v_t^2}{4c_t} \tag{5–2}$$

ii. The firm can attempt to cover its entire customer base, M, by jointly addressing customers in all market segments - a strategy that works only if the firm sets a selling price for its brown product low enough such that it matches the moderately low willingness to pay of the Greens segment customers for traditional product attributes (i.e., $p = \theta v_t q_t$). This allows the firm to extract the entire consumer surplus from the Greens segment, whereby create a positive consumer surplus for Browns and Fence-Sitters consumers that is higher than the value they otherwise would have received from the existing brown product and that galvanizes them into purchasing the Brown product. In this line, the profit maximization problem of the monopolist firm is given by $\Pi_1^{ii} = M(\theta v_t q_t - c_t q_t^2)$ with $q_t \geq 0$, based on which the optimal values of traditional quality and profit are obtained as follows:

$$q_t^* = \frac{\theta v_t}{2c_t} \tag{5–3}$$

$$\Pi_1^{ii*} = \frac{M\theta^2 v_t^2}{4c_t} \tag{5–4}$$

Based on the analytical framework established above, the optimal profits of the firm obtained under each pricing regime (i.e., $\Pi_1^{i\,*}$ and Π_1^{ii*}) can be evaluated and under what conditions each option will yield the biggest payoff according to the profit-maximization criteria can be identified.

Proposition 5.1. *Under the Greening Off strategy, the firm positions the price of its existing brown product on the consumer value sought by Greens segment consumers, and hence offers mainstream appeal if and only if* $\theta > \sqrt{1 - r_G}$.

Proof. It is obtained by comparing the optimal profit function $\Pi_1^{i\,*}$ given in equation (5–2) with the optimal profit function Π_1^{ii*} given in equation (5–4). □

It is seen in Proposition 5.1 that two main characteristics of the Greens segment affects the parameters by which the firm formulates the pricing strategy for its existing brown product. The pricing policy under the Greening Off strategy appears to have a direct link to the way standard features of the brown product are attributed to Greens segment consumers and to the relative size of Greens market segment. At this point, the firm would do well to ask itself this question: Are sufficient numbers of Greens consumers willing to pay more for the non-environmental features I offer? If the prevailing brown product is likely to receive high degree of acceptance from the Greens consumers and serveable Greens segment population is moderately high, then seeking to reach out to all three segments in the market is very likely to translate into higher return in revenues and profits than those earned by concentrating only on Browns and Fence-Sitters segments. If the value of θ is low, the firm earns smaller profit margins from its complete market coverage pricing approach, and the increase in the number of units sold may fail to turn those into growth in revenues and profits - in fact, quite the opposite can occur.

5.3.2 Greening Out Strategy

Under this strategy, driven by the underlying fact that the burgeoning, highly desirable Greens segment shoppers have unmet needs and wants that are attributed to their environmental concerns and that await a solution, the brown firm discontinues selling its brown product and embarks upon an entirely new or different product concept - i.e., a green product q_e with minimal, if not zero, environmental impact. The primary end goal of this radical change is to get an environmentally preferable substitute for the traditional brown product into the Greens and Fence-Sitters consumers' hands - who place a high priority on environmental quality. Nevertheless, the firm can also improve consumer appeal for its environmentally-sensitive product by positioning its environmental features into advantages that resonated with Browns segment consumer values. When Browns segment consumers are convinced of the desirable "non-green" benefits of an environmentally friendly product (e.g., cost-savings), they are more inclined to adopt it. Then, the firm's new green product can appeal to merely relatively lucrative Greens and Fence-Sitters market segments and command a price premium or serve overall consumer market by offering "green" benefits that credibly showcase "non-green" value Browns segment consumers desire at a lower price. The two distinct pricing strategies that enable the firm to capture the full possible value of its new green offering by strongly influencing consumer purchase decisions can be described as follows:

i. The firm can vary its green product's price according to Greens and Fence-Sitters segment customers' latitude of price acceptance, which is a range of possible prices within which price changes have little or no impact on these consumers' purchase decisions, expressed by $v_e q_e$. The relative impact of such pricing policy on Browns consumers' purchase intentions or perceptions of price fairness will be adverse though, unless environmental benefits of the product appeal to their self-interest (i.e., if θ is not equal to 1). By pricing in this manner, the firm may very well raise its profit margins per green product to $v_e q_e - c_e q_e^2$, but suffer from a guaranteed decrease in its sales, of value Mr_B, due to exclusion of Browns from the consumption activity. Then, the profit maximization problem of the monopolist firm gets the form of $\Pi_2^i = M(r_G + r_F)(v_e q_e - c_e q_e^2) - N$ with $q_e \geq 0$, yielding the optimal values for environmental quality and profit as follows:

$$q_e^* = \frac{v_e}{2c_e} \tag{5–5}$$

$$\Pi_2^{i\,*} = \frac{M(r_G + r_F)v_e^2}{4c_e} - N \tag{5–6}$$

ii. In a continuing effort to increase the collective market share of its new green offering through additionally capturing mainstream Browns segment customers, the firm can push the sales of the green product by adjusting its prices according to Browns' willingness to pay for the environmental benefits it offers (i.e., $\theta v_e q_e$). Pricing based on Browns' valuation on green product not only induces these customers to purchase the green product they otherwise would not have considered, but also creates a positive consumer surplus for Greens and Fence-Sitters who are willing to pay higher prices - and so who will benefit from lower prices. This increases the number of customers that can be served under the previous pricing option (i.e., $M(r_G + r_F)$) to $M(r_G + r_F + r_B)$. Based on that the monopolist firm's profit maximization problem becomes $\Pi_2^{ii} = M(\theta v_e q_e - c_e q_e^2) - N$ with $q_e \geq 0$, and the optimal values for environmental quality and profit are obtained as follows:

$$q_e^* = \frac{\theta v_e}{2c_e} \tag{5–7}$$

$$\Pi_2^{ii*} = \frac{M\theta^2 v_e^2}{4c_e} - N \tag{5–8}$$

Now two pricing regimes - on the basis of their corresponding profits (i.e., Π_2^{i*} and Π_2^{ii*}) - the firm should consider under the Greening Out strategy to transform its new green product into a profitable offering can be compared, and so what factors are driving each pricing strategy choice can be identified.

Proposition 5.2. *Under the Greening Out strategy, the firm reaps higher profits with setting its green product's price such that it is a representative of what Browns segment consumers are willing to pay, only when* $\theta > \sqrt{1 - r_B}$.

Proof. It is obtained by comparing the optimal profit function Π_2^{i*} given in equation (5–6) with the optimal profit function Π_2^{ii*} given in equation (5–8). □

Nearly mirroring the findings corroborated in Proposition 5.1, Proposition 5.2 shows that pricing decisions under the Greening Out strategy are driven by two main constraints: (1) how much Browns segment consumers are willing to pay for environmental benefits, and (2) how many consumers in the Brown segment can be served by a green product. Then, two major characteristics of the Browns market segment change both the profit margin and market share side of the equation. On the profit margin side, firm's failure to add value-added benefits (e.g., cost-effectiveness or health benefits) into its green product implies the green product would not be appealing to Browns customers who are indifferent or hostile to green attributes in general. When the firm's green product is perceived as "too green" by Browns customers, their willingness to pay drops off and the firm would probably not be able to capitalize on its efforts to serve more varied customer tastes in market. On the market share side, a potential loss in the firm's bottom line due to Browns' unresponsiveness to greenness can potentially be offset by a relatively higher size of the Browns' segment in overall consumer market. If a significant portion of the firm's current customers fall within the Browns segment, then the firm can stand to gain from pricing according to Browns' valuation and so broadening the mainstream appeal even if they do not think the green product is relevant to their shopping needs.

5.3.3 Greening Up Strategy

Under the Greening Up strategy, the firm's existing brown product is streamlined to reduce waste, cut energy and water use, lower carbon-emissions, minimize use of materials, and so forth - in other words, the firm keeps delivering its basic brown product with traditional quality q_t, but that provides at least one additional environmental benefit represented by q_e. The additional environmental benefit(s), properly connected with tastes and buying behavior of shoppers having differing environmental attitudes, help these customers better appreciate the prevailing product, which in turn merit the firm's asking for higher prices for additional environmental features that add cost to its existing brown product. Then, by deciphering what the average customer in a targeted segment wants and what green feature(s) to add into the brown product, the firm can extract additional economic value from its existing product, while keeping its current business humming. Related to this point, because overall consumer market it targets is sliced into Browns, Fence-Sitters and Greens segments, the firm can choose among three different pricing schemes to better leverage the heterogeneity in valuation that these customers put on its greened-up product:

i. The firm can equate the price of its greened-up product (q_t, q_e) with Fence-Sitters segment consumers' willingness to pay which is given by $v_t q_t + v_e q_e$. Offering the same brown product with additional environmental benefits at such price points, however, may cause Browns and Greens segment consumers turn their back on the firm, because the value these consumers accord to the firm's envisioned product (i.e., $v_t q_t + \theta v_e q_e$ and $\theta v_t q_t + v_e q_e$, respectively) would be misaligned with its revised price - unless θ is equal to 1. Browns and Greens would resist the "overpriced" environmental benefits and basic product features they found less motivating, respectively, and the firm would have to yield up these two consumer segments. In this case, relative price hikes turn the size of addressable market size downward to Mr_F, and the firm faces the profit-maximization problem stated by $\Pi_3^i = Mr_F(v_t q_t + v_e q_e - c_u(q_t + q_e)^2) - Fq_e^2$ with $q_t, q_e \geq 0$. Assuming that the necessary conditions for optimality hold (i.e., $Fv_t \geq Mr_F(v_e - v_t)c_u$ and $v_e > v_t$), the optimal solution can then be obtained as follows:

$$q_t^* = \frac{v_t}{2c_u} - \frac{Mr_F(v_e - v_t)}{2F} \tag{5–9}$$

$$q_e^* = \frac{Mr_F(v_e - v_t)}{2F} \tag{5–10}$$

$$\Pi_3^i = Mr_F\left[\frac{v_t^2}{4c_u} + \frac{Mr_F(v_e - v_t)^2}{4F}\right] \tag{5–11}$$

ii. Instead of appending environmental benefits at raised prices that are balanced against Fence-Sitters' willingness to pay, the firm can charge what the combination of traditional and environmental attributes designed into the greened-up product is worth to Greens segment consumers who are loath to pay high prices for non-green attributes - such that $p_u = \theta v_t q_t + v_e q_e$. From the Fence-Sitters' perspective, such a pricing approach should mean that these Fence Sitters' perceived benefits from purchasing the greened-up product would outweigh its costs, and they would be willing, even eager, to buy the greened-up product. The ramification of how Browns would react to moderately set prices that are aligned with Fence-Sitters' willingness to pay is dependent upon the relative values of $v_e q_e$ and $v_t q_t$. If $v_t q_t \geq v_e q_e$, then the price resonates with willingness to pay of the Browns segment consumers who in turn gravitate towards the greened-up product and so the firm holds onto the entire addressable market. Otherwise, they do not see the price as indicative of what they should pay for a "refreshed" brown product with elevated environmental performance and resist to make a purchase. Comparison of these two scenarios analytically reveals that the latter scenario is not a viable option and so the profit-maximizing firm faces the problem given by $\Pi_3^{ii} = M(\theta v_t q_t + v_e q_e - c_u(q_t + q_e)^2) - Fq_e^2$ with $q_t, q_e \geq 0$. Then, assuming that the necessary conditions for optimality hold (i.e., $\theta v_t < v_e < \theta v_t(1 + \frac{F}{Mc_u})$), the optimal traditional and environmental qualities of the greened-up product along with the firm's profits are derived as follows:

$$q_t^* = \frac{\theta v_t}{2c_u} - \frac{M(v_e - \theta v_t)}{2F} \tag{5–12}$$

$$q_e^* = \frac{M(v_e - \theta v_t)}{2F} \tag{5–13}$$

$$\Pi_3^{ii} = M\left[\frac{\theta^2 v_t^2}{4c_u} + \frac{M(v_e - \theta v_t)^2}{4F}\right] \tag{5–14}$$

iii. In stark contrast to basing the price on Greens' willingness to pay, the price tag of the firm's greened-up product can reflect Browns segment consumers' underlying value equation for the traditional and environmental benefits the "refreshed" brown product offers - in other words, $p_u = v_t q_t + \theta v_e q_e$. Based on a reasoning similar to that detailed in the preceding item, the firm's profit maximization problem is so expressed as $\Pi_3^{iii} = M(v_t q_t + \theta v_e q_e - c_u(q_t + q_e)^2) - F q_e^2$ where $q_t, q_e \geq 0$. Given that the necessary conditions for optimality holds (i.e., $v_t < \theta v_e < v_t(1 + \frac{F}{Mc_u})$), the optimal solution is derived as follows:

$$q_t^* = \frac{v_t}{2c_u} - \frac{M(\theta v_e - v_t)}{2F} \tag{5–15}$$

$$q_e^* = \frac{M(\theta v_e - v_t)}{2F} \tag{5–16}$$

$$\Pi_3^{iii} = M\left[\frac{v_t^2}{4c_u} + \frac{M(\theta v_e - v_t)^2}{4F}\right] \tag{5–17}$$

An evaluation of these possibilities leads to the following proposition.

Proposition 5.3. *Under the Greening Up strategy:*

- *If $1 \leq \frac{v_e}{v_t}$, the firm's optimal choice is to price based on the fence-sitters segment and realize profits of $\Pi_3^{\mathrm{i}\,*}$ or price based on the green segment and realize profits of $\Pi_3^{\mathrm{iii}*}$;*
- *If $\theta < \frac{v_e}{v_t} < 1$, the firm's optimal choice is to price based on the brown segment and realize profits of $\Pi_3^{\mathrm{ii}\,*}$; and*
- *If $\theta \geq \frac{v_e}{v_t}$, the firm should not adopt this strategy choice.*

Proof. It is obtained by comparison of the optimal profit functions $\Pi_3^{i\,*}$, Π_3^{ii*} and Π_3^{iii*} given in equations (5–11), (5–14) and (5–17), respectively. □

Proposition 5.3 shows that under the Greening Up strategy the firm should use different pricing regimes depending on whether the marginal valuation of traditional quality v_t is strictly greater than the marginal valuation of environmental quality v_e, and if so, whether Browns responsiveness to environmental benefits integrated into the existing brown product θ is less than the ratio v_e/v_t. Before using a pricing regime for its greened-up product, the firm should be fully aware of if environmental attributes designed into its brown product enhance the product's ability to perform its intended function in addition to providing environmental benefits. When environmental attributes perform equally well or better than traditional alternatives, the firm should choose the pricing strategy shaped by Fence-Sitters segment or Greens segment consumers. Said another way, the firm should equate the price of its greened-up product with

Fence-Sitters segment consumers' willingness to pay $v_t q_t + v_e q_e$ or with Greens segment consumers' product valuation $\theta v_e q_e + v_t q_t$, only if environmental benefits of the greened-up product are viewed as a new source of added value. Otherwise, the firm's pricing strategy is dependent upon how the environmental attributes of the greened-up product is perceived by the Browns segment consumers. If green is the only (or even main) benefit the environmental attributes provide, the Browns consumers will be reluctant to pay premiums for the existing brown product with elevated environmental performance. In these instances, premium pricing needs to be justified through another benefit (e.g., fuel-efficiency) so that Browns can be attracted to the refreshed brown product offered at a higher price. If higher prices cannot be backed up by one of these two factors, the firm is better off not choosing the Greening Up strategy.

5.4 Implementation Considerations

Firms may choose to green their products due to economic and noneconomic pressures from their consumers, business partners, governments, citizen groups or other stakeholders. This section focuses on economic and environmental issues germane to green products, and examines how the nuances of the green market environment (i.e., relative sizes of green consumer segments, and consumers' shopping aspirations and valuations) create incentives for a firm to adopt a green product strategy. To understand why and how the firm responds to these incentives, the analysis here concentrates on the net gains (as compared to the current brown product setting and as compared to other green strategy) of adopting each green product strategy. The analysis here is characterized by a major challenge: an analytical comparison of strategies is out of reach due to the complexity associated with the feasibility conditions of each strategy. Therefore, the analysis resorts to a numerical experiment with a certain number of cases and with an extensive set of parameter values to provide the basis for the discussion of important insights (See Appendix H for numerical data and complete results).

As is evident from the analysis of each strategy choice in preceding sections, the terms driving the results are the relative sizes of each market segment (i.e., r_B, r_F and r_G) and the relative marginal valuations for traditional versus green product attributes (i.e., v_t versus v_e). As a starting point for setting the portion of a firm's current customers falling within each segment, the results of the 2002 Roper survey data cited earlier are used. Based on the figures represented in Section 5.2.1, the values of r_B, r_F and r_G are set at 0.52, 0.33 and 0.15, respectively. It is worthy noting that these segments are not static and their relative sizes change over the years. For instance, GfK Roper Consulting have been tracking consumer attitudes since 1990, and a comparison of their data between 2005 and 2007 shows that there are changes in the percentages ascribed to each of the five segments: The number of the greenest consumers - the True Blue Greens and Greenback Greens - double in two years, from 20% to 40%. This indicates that consumers get greener over time, and in order to incorporate such dynamic nature of green market segments, two additional cases are considered: (1) a segmentation dividing the green landscape into Browns, Fence-Sitters and Greens such that $r_B = 0.15$, $r_F = 0.33$ and $r_G = 0.52$, respectively; and (2) a market that is apportioned equally among these three consumer segments so that $r_B = 1/3$, $r_F = 1/3$ and $r_G = 1/3$. As far as the marginal valuation on traditional quality v_t and marginal valuation on environmental quality v_e are concerned, it is difficult to define a range of plausible exact values. Thus, their relative magnitudes are considered by means of setting the value of v_t at 8, and varying the ratio of v_e to v_t to be 0.5 to 1.0 to 2.0. Finally, for the parameter $\theta \in (0, 1)$, a wide range of parameter values are considered by setting its value at 0.1 intervals from 0 to 1. On the supply side, the values of cost coefficients c_t, c_e and c_u are set at \$4, \$6 and \$5 to be consistent with recent literature on product design (e.g., Chen (2001)). Likewise, the values of the fixed cost of product redesign parameter F are set at \$20, \$40 and \$60, while the values of the fixed cost of new product introduction parameter N are set at \$4, \$12 and \$16.

5.4.1 Economic Consequences

The computational results represent the substantial impact of the interplay between marginal valuations of traditional and environmental qualities on the relative profitability of the Greening Off, Greening Out and Greening Up strategies. For the values of marginal valuation on environmental quality v_e less than or equal to those of marginal valuation on traditional quality v_t (i.e., $v_e/v_t \leq 1$), the Greening Off strategy (i.e., not incorporating green attributes) is always more profitable. This is true even when the fixed cost of product redesign F and fixed development cost of a new green product N are considerably low, and even when there are substantial numbers consumers in the market who are potentially receptive to a green appeal. For example, as can be seen in Table 5-1, the Greening Off strategy always dominates the Greening Out and Green Up strategies when $v_e/v_t \leq 1$, regardless of how substantial the Greens consumer segment is for the firm (e.g., when $r_G = 0.33$ or $r_G = 0.52$) and of the cost efficiency of designing green attributes into a product (i.e., when $F = 20$ and $N = 4$). This implies that when environmental attributes are perceived as less effective or not having the same value as the more familiar traditional attributes, it deters a firm not only from replacing its existing brown product with a new green product but also from greening up its existing brown product through small adjustments.

On the other hand, when these perceptions decline in a way so that v_e becomes superior to v_t (i.e., $v_e/v_t > 1$), the firm is more likely to capitalize on offering a greened-up product or launching a new green product. In this case, these two green product strategies can turn out to be economically viable options even in the presence of considerably high fixed costs of F and N, and even when the Greens segment is not prominent within the firm's current customer base. For example, Table 5-2 shows that the Greening Out strategy dominates the Greening Off strategy when $v_e/v_t > 1$, even though 52% of the firm's current customers fall within the Browns segment and the fixed cost of green product development is considerably high (i.e., $N = 12$). Based on that the ratio v_e/v_t can be considered as an index to measure the attractiveness of integrating green attributes into a product design. When the value of this index is less than or equal to 1, it is not in the firm's self-interest to invest in green product strategies even if its current consumers are very responsive to changes in greenness and/or the size of the Greens market segment is high. By contrast, when $v_e/v_t > 1$, the higher the value of the index, the more attractive it is for a firm to offer a product with environmental attributes rather than offering a brown product characterized by just traditional attributes.

The comparison of the optimal profit values under the Greening Up and Greening Out strategies - given that $v_e/v_t > 1$ - to answer under what conditions a greened-up product is economically more attractive to a firm than a new green product, or vice versa, reveals that the managerial choice between these two strategies is overwhelmingly driven by two factors: (1) how substantial the Browns segment is within the current consumer space for the firm (i.e., r_B), (2) how environmental benefits of a product resonate with the Brown segment consumers' values (i.e., θ), and (3) the fixed cost of green product introduction (i.e., N). The numerical analysis shows that offering a greened-up product is more likely to be profitable when r_B and θ are relatively large while N is not very low. For instance, as presented in Table 5-3, unless the majority of the consumer market is represented by the Browns segment consumers (e.g., when $r_B = 0.15$ or $r_B = 0.33$), the firm is always better off using the Greening Out strategy to eco-innovate, even if it means incurring substantial costs of developing an entirely new green product concept (i.e., $N = 24$). When the majority of consumers in the market fall into the Browns segment, choosing between a Greening Out and Greening Up strategy should be guided by the fixed cost of green product introduction and by whether environmental attributes provide tangible, direct benefits to this meaningful number of Browns consumers beyond offering environmental benefits. Given that $r_B = 0.52$, Table 5-4 points out that the Greening Out strategy is always a better option than the Greening Up strategy if $N = 4$. However, for higher values of N (e.g., $N = 12$ or $N = 24$), it is observed the Greening Up strategy can dominate the Greening Out strategy in cases where environmental attributes appeal to the Browns segment consumer' self-interest (i.e., $0.5 < \theta \leq 0.7$). In this context, the parameters r_B and θ represent how prominent the Browns segment is within the green consumer market for the firm. When the Browns segment decreases in importance, adding green features into the existing brown product for cultivating additional revenue does not seem worth the effort and replacing the prevailing brown product with a new green product would make more sense.

5.4.2 Environmental Consequences

The previous section points out that a brown firm can benefit financially from an environmentally friendly approach to product design in certain circumstances, yet it also raises a pivotal issue regarding the firm's environmental-financial performance calculus: to what extent a green product development strategy creates environmental benefits while providing economic payoffs to the firm. The strategy choice cannot be judged by financial criteria alone since creating environmental benefits through creating bottom line benefits should only be one part of choosing a green product strategy. In this context, the environmental profile of a firm that would adopt either the Greening Up strategy or Greening Out strategy can be compared numerically by means of taking the aggregate sum of environmental quality supplied in the greened-up product or new green product, respectively, and the issue of under what conditions the firm adopts a strategy not only because 'it is the most profitable thing to do' but also because 'it is the right thing to do' can be addressed.

Before focusing on the key drivers of satisfying firm's economic and environmental objectives together, the first attempt here is to find out which way of incorporating environmental friendliness into the product design can help the firm achieve a higher environmental performance - regardless of its financial aspirations. The reasoning behind this quest can be explained by the fact that a firm has to benefit the environment at a certain degree with its product to continue doing well financially, or it will eventually hit problems that in turn could cause struggles with staying in the market. For all combinations of parameter values used in the numerical analysis, it turns out that developing a new green product from scratch offers superior environmental benefits, even though greening up an existing brown product through incremental changes can offer considerable environmental benefits. Regardless of how substantial the Greens consumer segment is for the firm (i.e., no matter whether r_G is equal to 0.15, 0.33 or 0.52), it is observed that a firm must jump-shift to an entirely new product concept in order to achieve significant, not just incremental, reductions in its environmental impact. This finding is demonstrated in Table 5-5 by different values of θ, and r_B and r_G. Note that this result holds even when environmental benefits designed into the new green product do not appeal to Browns segment consumers' self-interest (i.e., for the values of θ close to 0).

This conclusion appears to be contrary to the prevailing view claiming that greening out is not an approach firms are especially good at minimizing the environmental impacts of their products. According to Hopkins (2010), for instance, trying to eliminate environmental impacts all at once is not the best option to help the environment: It is the incremental changes that carry product designs toward the no-impact outcomes and so that achieve cumulatively significant environmental benefits. Our numerical analysis shows that this is not necessarily true. The fact is, under the Greening Up strategy, an existing product can only be adjusted until at a certain degree before it becomes necessary to leap to an entirely new product concept in order to meet the same customer needs with significantly reduced environmental impact. Greening a product by making adjustments (e.g., in raw materials or packaging) leaves a firm with the same product concept, meaning that the firm will be limited by its existing product concept.

It is also observed that doing good by incorporating environmental friendliness into product design and doing well financially is not supposed to be a either-or proposition. A firm can achieve both goals simultaneously, yet it must be beware of false choices when considering the green product strategies. The conditions under which the Greening Up or Greening Out strategy outperforms the Greening Off strategy besides outgreening is overwhelmingly characterized by consumers' marginal valuation on traditional and environmental qualities, i.e., v_t and v_e, respectively. As the difference between v_e and v_t increases (i.e., the value of the index v_e/v_t gets higher), the Greening Out strategy represents the opportunity to at once solve pressing environmental issues while helping the firm grow its profits - even though the firm would be in the face of higher unit costs of production (since $c_e > c_t$) and might be facing a high fixed cost of green production introduction (e.g., $N = 12$). On the other hand, a brown firm can create both bottom-line and environmental benefits by implementing the Greening Up strategy (even when the fixed cost of product redesign is very high such that $F = 60$), only if v_e is considerably higher than v_t, the Browns segment is prominent within the current customer base (i.e., $r_B = 0.52$, $r_F = 0.33$ and $r_G = 0.15$) and the environmental features designed into the brown product offers the promise of more than what is good for the environment (i.e., if the value of θ is large enough).

5.5 Summary

Consumers are waking up. The environment has become a fiduciary issue and consumers are starting to vote with their pocketbooks, choosing to buy greener products and supporting companies perceived to be green. In response, companies are moving beyond environment, filling up the pipeline of greener products. The fact is, there is money to be made in new green marketplace and many companies should see addressing environmental concerns as a potential value-add rather than a cost to be minimized. They should look for new ways to leverage green thinking into their product designs. Most encounter a fork in this road to sustainability. Should they offer greener products that represent small enhancements to their existing brown products by replacing virgin materials with recycled content, designing packaging to be refilled, and so forth? Or should they offer a new green product that is unabashedly green? Many green products on the market nowadays represent small tweaks to existing ones. For example, washing machines save water and energy by tumbling clothes on a horizontal axis as opposed to a vertical axis. Although these are needed technical achievements as well, the reductions in environmental impact they represent may not be enough to meet future consumer needs in a sustainable fashion as backed up by the findings of this chapter. The chapter points out that finding solutions to environmental degradation and achieving environmental protection requires a radical change in the product design. Simply put, companies must leap rather than tweak.

Table 5-1. Comparison of Greening-Off, Greening-Out and Greening-Up strategies when $\theta = 0.4$, $F = 20$ and $N = 4$

				Profits		
v_e/v_t	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up
0.5	0.33	0.33	0.33	26.7	0.4	5.9
0.5	0.15	0.33	0.52	19.2	1.7	5.9
1.0	0.33	0.33	0.33	26.7	13.8	0
1.0	0.15	0.33	0.52	19.2	18.7	0

Table 5-2. Comparison of Greening-Off and Greening-Out strategies when $v_e/v_t > 1$, $\theta = 0.4$ and $N = 12$

			Profits	
r_B	r_F	r_G	Greening-Off	Greening-Out
0.52	0.33	0.15	34.0	39.2
0.33	0.33	0.33	26.7	59.1
0.15	0.33	0.52	19.2	78.7

Table 5-3. Comparison of Greening-Out and Greening-Up strategies when $v_e/v_t > 1$ and $F = 20$

θ	r_B	r_F	r_G	Profits Greening-Out	Profits Greening-Up
0.4	0.15	0.33	0.52	66.7	19.3
	0.33	0.33	0.33	47.1	19.6
0.6	0.15	0.33	0.52	66.7	35.2
	0.33	0.33	0.33	47.1	35.2
0.8	0.15	0.33	0.52	66.7	19.3
	0.33	0.33	0.33	47.1	19.6

Table 5-4. Comparison of Greening-Out and Greening-Up strategies when $v_e/v_t > 1$, $r_B = 0.52$, and $F = 20$

N	θ	Profits Greening-Out	Profits Greening-Up
4	0.5	47.2	19.3
	0.6	47.2	35.2
	0.7	48.3	44.8
5	0.5	39.2	19.3
	0.6	39.2	35.2
	0.7	40.3	44.8
6	0.5	27.2	19.3
	0.6	27.2	35.2
	0.7	28.3	44.8

Table 5-5. Comparison of environmental performance of Greening-Out and Greening-Up strategies when $v_e/v_t > 1$, $N = 4$ and $F = 20$

θ	r_B	r_G	Total environmental quality Greening-Out	Total environmental quality Greening-Up
0.3	0.52	0.15	6.4	2.2
	0.33	0.33	8.9	2.2
	0.15	0.52	11.3	2.2
0.5	0.52	0.15	6.4	2.2
	0.33	0.33	8.9	2.2
	0.15	0.52	11.3	2.2
0.7	0.52	0.15	9.3	8.0
	0.33	0.33	8.9	8.0
	0.15	0.52	11.3	8.0

CHAPTER 6
CONCLUSION AND FUTURE RESEARCH DIRECTIONS

The maturing of greening as a consumer phenomenon and its decided shift from the fringe into the mainstream are changing the rules by which companies compete in the competitive landscape. It used to be that consumers simply expected the products they bought to work well, be sold in a nearby store, sport a familiar brand name and be affordable. The rules have changed. Today, meeting consumers' new heightened needs is a challenging task. Once seemingly short checklist for achieving market success now includes minimizing the environmental impacts of the consumer products at every phase of their life-cycle. Companies looking to sustain their businesses long into the future must now build legitimately sustainable brands that balance age-old benefits of quality, performance, affordability and convenience with the lowest impact possible on the environment, and with due concern for social considerations. This presents the businesses the need to jungle traditional product considerations with an extremely varied and highly complex list of issues involving the entire supply chain.

Designing products for minimal environmental impact can be tricky. What may appear to be an environmental benefit may actually result in little or no added environmental value. Hybrid cars, for example, save energy but the batteries they contain represent a potentially significant source of hazardous waste. It can also be argued that there is no such thing as a truly "green" product, because every product, no matter how thoughtfully designed, uses resources and creates waste. This implies that "green" is a relative term, with some products being greener for certain reasons or in certain circumstances. This does not erect a barrier to companies who are looking to grow their businesses by reaping the benefits of expanding green markets, though. To stay competitive and meet the challenges of sustainable development, many companies attempt to minimize their products' environmental and health-related risks by addressing the specific environmental issues most relevant to their consumers. One way to address consumers' various environment-related product concerns is through innovation.

Innovating for environment inspires products that address the new rules of balancing consumers' needs with sustainability considerations. Typically, it can be carried out at two different levels, each corresponds to either the Greening Up strategy or Greening Out strategy. The Greening Up strategy involves redesigning an existing product to reduce its environmental impact by making incremental adjustments in raw materials, packaging, and so forth. The Greening Out strategy can be defined as developing entirely new products capable of performing the same function as existing ones but with significantly less environmental impact. As can be seen in Chapter 4 and Chapter 5, environmental innovation represents opportunities to solve pressing environmental issues at different levels while better meeting consumer needs. Among its significantly enhanced environmental and consumer benefits, it brings exciting opportunities for companies to help grow their top-line sales and even evolve and transform their businesses profitably to better compete within the rules of a more sustainable future.

Although there are many opportunities associated with designing and offering greener products, challenges abound and company managers should consider the challenges before choosing and implementing either the Greening Up strategy or the Greening Out strategy. For starters, green consumer segments are complex and selecting the right consumer to target is critical to the success of each green product strategy. As described in detail in Chapter 1 and Chapter 5, consumers can be segmented into the five segments: True Blue Greens, Greenback Greens, Sprouts, Grousers and Basic Browns. Knowing that there are many different types of green consumers, it is essential for company managers to keep in mind that there are many different kinds of environmental issues of concern ranging from hazardous waste to energy efficiency - that concern even the Basic Browns and Grousers. The fact is, not all consumers are concerned about all environment-related issues and this underlines the importance of pinpointing the consumers who will be attracted most to a greened-up product or to a new product that is unabashedly green.

Chapter 5 shows that appealing to consumers' self-interest is a factor, too. Even though environment is important to many consumer segments, the number one reason why consumers buy greener products is not to protect the environment but to protect their own health or to meet their basic needs. So it is critical not to focus too heavily on environmental benefits at the expense of primary benefits such as saving money. In other words, companies should design their greener products by positioning their environmental benefits as an important plus or by incorporating the environment as a desirable extra benefit. This approach can help them broaden the appeal of their greener products way beyond the niche of deepest green consumers and help them overcome a premium price hurdle. The bottom line is it is crucial to integrate environmental benefits into a product design that neatly translate into something direct and meaningful to the customers.

What are the next steps that can be taken to further the research in green product design? In the past, premium pricing, poor performance, brand names no one had ever heard of and vaguely worded environmental claims made consumers suspect green products. The consumer market had an intuition that if green products do not work better or more efficiently than their brown counterparts, then they should cost less, not more. But this is changing nowadays. Consumers' reluctance to pay premiums for green products is softening as they begin to comprehend the impact environment-related issues have had on their lives over the last few decades. Fast growing sales of green products demonstrate that the greater the perceived threat of an environmental problem, the more prepared the consumers to pay premium prices for the green products offered in response to that problem. However, being less price sensitive when it comes to green products is not the only consumer characteristic that makes green consumers valuable target shoppers. Green shoppers are a valuable customer target, because they represent a consumer segment who buy more products on each store visit, who visit the store more regularly, and who demonstrate more brand and retailer loyalty in their purchasing behavior. They are active consumers who buy more and shop more often as opposed to the average shopper, and they are generally not bargain hunters. More importantly, once a green product has captured these shoppers' attention, it tends to create brand stickiness by retaining their loyalty through repurchase. In this research, it is assumed that there are no repeat purchases and there is only one buying opportunity given to the consumer market. However, on the basis of the discussion above, incorporating repeat purchase behavior of green consumer in the existing context would be an interesting extension.

With green awareness now squarely mainstream, many companies are now catering to newly green consumers by launching products while advertising them with environmental claims that these products have greener features to reap the benefits of expanding green markets. Today, the supermarket shelves are emblazoned with all sorts of messages about the environmental performance of various products. In line with an average of 79% increase in the amount of green products per store since 2007, green advertising has increased tenfold over the past 20 years and almost tripled since 2006[1] . Today on practically every company website one can find corporate environmental responsibility reports with titles such as "Sustainability Report" or "Environmental Health and Safety". As of 2009, more than 75% of S&P 100 companies has special website sections disclosing their environmental policies and performance[2] . At the same time,

[1] http://www.theecologist.org/News/news_round_up/274429/greenwash_taints_most_ecofriendly_claims.html, accessed September 7, 2012.

[2] http://www.globalaffairsjournal.com/archive/Winter-Spring2009/Alves.pdf, accessed September 7, 2012.

more and more companies are engaging in greenwashing, intentionally or not, and misleading consumers regarding the environmental benefits of their product(s). Over 98% of environmental claims made by products surveyed by TerraChoice Environmental Marketing in 2009 were guilty of greenwashing[3] .

The risks of backlash are high. The skyrocketing prevalence of greenwashing can have profound negative effects on consumer confidence in green products, eroding the consumer market for green products. Consumers boycott products bearing environmental claims nowadays. To complicate matters, corporate efforts hinting at aspirations to be green can attract critics. Accusations of greenwashing can emanate from many sources including government entities, environmentalists, consumers and competitors, and it can be detrimental to a company's reputation. The U.S. Federal Trade Commission, for instance, publicly spanked Mobil Corporation that promoted its Hefty plastic trash bags as photodegradable. Likewise, companies can face regulatory punishment for engaging in environmentally false advertising. Based on that an interesting direction for future research would be empirically demonstrating the incidence of greenwashing, describing its effects on green consumer market and on how firms implement green product development strategies to stay competitive in green landscape, and developing a framework that examines the organizational drivers of each strategy choice under the threat/risk of greenwashing.

It is apparent that consumers' perceptions of the environmental impacts of products are increasingly factoring into their decisions of what, where and how often they purchase. However, consumers often do not have the ability to verify products' environmental benefits (particularly in the absence of information on the packages or shelves identifying a specific product as environmentally responsible in one way or

[3] I. Alves, "Green Spin Everywhere: How Greenwashing Reveals the Limits of the CSR Paradigm," *Journal of Global Change and Governance*, Winter/Spring 2009.

another) and this can in turn create misperceptions and skepticism. Newly uncovered learning that is not correct can instantly upend a company's credibility and public image, resulting in a complete collapse in demand for its products. This necessitates products' environmental attributes being communicated honestly and qualified for believability. Related to this point, eco-certifications obtained from government agencies or non-profit advocacy organizations can provide green product endorsements that help clarify and bolster the consumers' understanding of products' environmental benefits. For example, the Energy Star label is a common certification that distinguishes particular electronic products as consuming up to 30% less energy than comparable alternatives. Similarly, Green Seal and Scientific Certification Systems emblems certify various product categories, and for a given fee, companies can have their products evaluated and monitored annually for certification. Based on that a second possible extension would be to incorporate endorsements and eco-certifications into the framework for green product development strategy choice analyzed in this research. Forming constructive partnerships or coalitions with expert third parties with respected standards for environmental testing can uncover ways to cut costs, improve the value of existing products and new products, and enhance public image. On the other hand, companies must also consider the environmental and financial trade-offs and complexity of their products, when seeking endorsements and eco-certifications.

In a headlong rush to attract green-leaning customers that would pay hefty premiums for green products, many brown companies are often tempted to offer the greenest of mainstream products. When it works, the combination of a brown and a green brand in the market allows those companies to calibrate those two offerings to their own strategic advantage. On the other hand, once launched, green products have a growing tendency to also steal customers from these companies' existing portfolio of brands. Add to that the challenge that no products stand alone. A new green product cannot be simply added into an existing product system in isolation, and creating a new green brand forces a company with a pre-existing brown brand in its current system to divide its resources rather than concentrate its efforts on the business at hand. Therefore, explicit incorporation of the capacity constraints should be an important extension. In order to surmount all the hurdles corresponding to capacity issues to their advantage and convert potential enemies into profitable allies, the managers of branded brown companies must not only understand in depth how green consumers and their green purchasing motivations differ markedly from brown consumers, but also carefully leverage their system in which brown and green products are envisaged to operate.

With increased awareness of environmental threats posed by products, consumers are now scrutinizing products' entire life-cycles and asking for visibility into how raw materials are sourced, and products are manufactured and shipped. Working with suppliers to meet consumer environmental demands should not be underestimated. With their intimate knowledge of their own materials, components and technologies, suppliers can offer critical support in reducing environmental impacts of products, resulting in new products and packaging and greened-up life-cycles that can establish competitive advantage. At this point, an extension by taking into consideration the strategies for partnering with suppliers can be valuable. Such an extension should also consider possible challenges. For example, a company can have a plethora of suppliers, many of which can be stretched out long distances around the globe, and they may be loath to disclose trade secrets. In addition, some suppliers may be new to environmental management and so be not capable of analyzing their materials, ingredients and process effectively.

Finally, the proliferation of green products is revealing out a widespread support for and an increasing understanding of the need to reduce environmental impact of the existing products. However, there is a major challenge faced by consumers, businesses, and governments: What constitutes a green product and according to whom? In current literature associated with green product development, an environmentally benign product is almost always characterized by a single environmental attribute, and so only one dimension of green (e.g., energy efficiency, toxicity and recyclability) is taken into consideration. More importantly, environmental impact of the two products are compared based on this unique attribute. This simple green metric may hide possible trade-offs. For instance, CPC - the makers of Mueller's pasta - found that converting to recycled carton material would actually add about 20% to the width of their package material and this would partially offset savings to the environment, considering the extra energy needed to ship new boxes. Using a single green metric can also overlook the fact that consumers' preferences exhibit different orders in different environmental attributes. Based on that developing a strategy choice model that explicitly incorporates multiple environmental attributes into the green product development, along with the trade-offs among them, would be interesting.

APPENDIX A
PROOF OF THEOREM 1

The Hessian of Π^A is negative semidefinite if and only if all 2 leading principal minors alternate sign such that $|H_1| \leq 0$ and $|H_2| \geq 0$. Based on that the joint concavity of Π^A in p_b^A and q_e^A is true if

$$2\alpha\left(2 + p_b^A - \alpha q_e^{A^2}\right) \geq \left(1 - \chi_b^A\right)\left(2\alpha q_e^A - 1\right)^2. \tag{A–1}$$

Assuming that the condition provided above is satisfied and so Π^A is strictly and jointly concave in p_b^A and q_e^A, the necessary conditions are sufficient for optimality and given by the following:

$$\frac{\partial \Pi^A}{\partial p_b^A} = 0 \quad \Rightarrow \quad p_b^A - \frac{1}{4\alpha} = \frac{1 + e^{p_b^A - \frac{1}{2\alpha} - \theta q_e^A}}{e^{p_b^A - \frac{1}{2\alpha} - \theta q_e^A}} \tag{A–2}$$

$$\frac{\partial \Pi^A}{\partial q_e^A} = 0 \quad \Rightarrow \quad p_b^A - \frac{1}{4\alpha} = \frac{\gamma q_e^A\left(1 + e^{p_b^A - \frac{1}{2\alpha} - \theta q_e^A}\right)^2}{\theta e^{p_b^A - \frac{1}{2\alpha} - \theta q_e^A}} \tag{A–3}$$

Combining these two expressions, it is obtained:

$$e^{p_b^A - \frac{1}{2\alpha} - \theta q_e^A} = \frac{\theta}{\gamma q_e^A} - 1 \tag{A–4}$$

and substituting this expression in equation (A–2) results in:

$$p_b^A = \frac{1}{4\alpha} + \frac{\theta}{\theta - \gamma q_e^A} \tag{A–5}$$

Combining equation (A–5) with equation (A–4) yields

$$\mathcal{G}\left(q_e\right) \equiv e^{\frac{\theta}{\theta - \gamma q_e^A} - \theta q_e^A - \frac{1}{4\alpha}} - \frac{\theta}{\gamma q_e^A} + 1 = 0, \tag{A–6}$$

which concludes the proof if $q_e^{A^*} \geq \frac{\sigma}{2\alpha}$. If $q_e^{A^*} < \frac{\sigma}{2\alpha}$, then the optimal value of q_e^A that maximizes Π^A gets equal to $\frac{\sigma}{2\alpha}$, since Π^A is assumed to be concave in q_e^A for any given value of p_b^A. Therefore, the monopolist's problem under the Accentuate strategy simplifies to maximizing Π^A with respect to p_b^A, based on which the first order condition is derived as follows:

$$\frac{\partial \Pi^A}{\partial p_b^A} = 0 \quad \Rightarrow \quad p_b^A - \frac{1}{4\alpha} = 1 + e^{-p_b^A + \frac{1+\theta\sigma}{2\alpha}} \tag{A–7}$$

It is seen from equation (A–7) that the optimal value of p_b^A implicitly solves the equation given by

$$\mathcal{L}\left(p_b^A\right) \equiv \left(p_b^A - \frac{1}{4\alpha} - 1\right) e^{p_b^A - \frac{1+\theta\sigma}{2\alpha}} - 1 = 0, \tag{A–8}$$

which concludes the proof. $\square$

APPENDIX B
PROOF OF THEOREM 2

The Hessian of Π^B is negative semidefinite if and only if all 3 leading principal minors alternate sign such that $|H_1| \leq 0$, $|H_2| \geq 0$ and $|H_3| \leq 0$. Based on that the joint concavity of Π^B in p_e^B, q_e^B and p_b^B is true if

$$\chi_b \chi_e^2 \left[(\theta - 2\alpha q_e (1-\chi_e))^2 + \chi_e \chi_b (\theta - 2\alpha q_e)^2 - \theta \left(2\chi_e \theta + \frac{1}{q_e} \right) \right] \leq 0. \quad \text{(B–1)}$$

Assuming that the condition given above holds and so Π^B is strictly and jointly concave in p_e^B, q_e^B and p_b^B, the necessary conditions are sufficient for optimality and given by the following:

$$\frac{\partial \Pi^B}{\partial q_e^B} = 0 \Rightarrow \theta \chi_e^B \left(1 - \chi_e^B\right) \left[p_e^B - \alpha \left(q_e^B\right)^2 \right] - 2\alpha q_e^B \chi_e^B - (\gamma + 2\tau) q_e^B - \theta \chi_b^B \chi_e^B \left[p_b^B - \alpha \left(q_b^*\right)^2 \right] = 0 \quad \text{(B–2)}$$

$$\frac{\partial \Pi^B}{\partial p_e^B} = 0 \Rightarrow p_e^B - \alpha \left(q_e^B\right)^2 = 1 + \chi_e^B \left[p_e^B - \alpha \left(q_e^B\right)^2 \right] + \chi_b^B \left[p_b^B - \alpha \left(q_b^*\right)^2 \right] \quad \text{(B–3)}$$

$$\frac{\partial \Pi^B}{\partial p_b^B} = 0 \Rightarrow p_b^B - \alpha \left(q_b^*\right)^2 = 1 + \chi_e^B \left[p_e^B - \alpha \left(q_e^B\right)^2 \right] + \chi_b^B \left[p_b^B - \alpha \left(q_b^*\right)^2 \right] \quad \text{(B–4)}$$

with

$$\chi_e^B = \frac{e^{\theta q_e^B - p_e^B}}{1 + e^{\theta q_e^B - p_e^B} + e^{q_b^* - p_b^B}}, \quad \text{(B–5)}$$

$$\chi_b^B = \frac{e^{q_b^* - p_b^B}}{1 + e^{\theta q_e^B - p_e^B} + e^{q_b^* - p_b^B}}, \text{ and} \quad \text{(B–6)}$$

$$q_b^* = \frac{1}{2\alpha}. \quad \text{(B–7)}$$

It is obvious from equations (B–3) and (B–4) that

$$p_e^B - \alpha \left(q_e^B\right)^2 = p_b^B - \alpha \left(q_b^*\right)^2, \quad \text{(B–8)}$$

based on which equation (B–2) can be restated as

$$\theta \chi_e^B \left\{ p_e^B - \alpha \left(q_e^B\right)^2 + 1 - \left(1 + \chi_e^B \left[p_e^B - \alpha \left(q_e^B\right)^2 \right] + \chi_b^B \left[p_b^B - \alpha \left(q_b^*\right)^2 \right] \right) \right\} = \left(2\alpha \chi_e^B + \gamma + 2\tau\right) q_e^B. \quad \text{(B–9)}$$

Substituting equation (B–3) into equation (B–9) yields:

$$\begin{aligned} \theta &= q_e^{B*}\left(\frac{2\alpha\theta\chi_e^B+\gamma+2\tau}{\chi_e^B}\right) \\ &= q_e^{B*}\left[2\alpha+(\gamma+2\tau)\left(1+e^{p_e^{B*}-\theta q_e^{B*}}+e^{\frac{1}{4\alpha}+\alpha\left(q_e^{B*}\right)^2-\theta q_e^{B*}}\right)\right] \end{aligned} \tag{B–10}$$

and this concludes the proof if $q_e^{B*} \geq \frac{\sigma}{2\alpha}$. If $q_e^{B*} < \frac{\sigma}{2\alpha}$, then the optimal value of q_e^B that maximizes Π^B gets equal to $\frac{\sigma}{2\alpha}$, since Π^B is given to be concave in q_e^B for any given values of p_e^B and p_b^B. Then, the monopolist's problem under the Architect strategy reduces to maximizing Π^B with respect to p_e^B and p_b^B, based on which the first order conditions are derived as follows:

$$\frac{\partial\Pi^B}{\partial p_e^B}=0 \;\Rightarrow\; p_e^B-\alpha\left(q_e^{B*}\right)^2=1+\chi_e^B\left[p_e^B-\alpha\left(q_e^{B*}\right)^2\right]+\chi_b^B\left[p_b^B-\alpha\left(q_b^*\right)^2\right] \tag{B–11}$$

$$\frac{\partial\Pi^B}{\partial p_b^B}=0 \;\Rightarrow\; p_b^B-\alpha\left(q_b^*\right)^2=1+\chi_e^B\left[p_e^B-\alpha\left(q_e^{B*}\right)^2\right]+\chi_b^B\left[p_b^B-\alpha\left(q_b^*\right)^2\right] \tag{B–12}$$

with $q_e^{B*}=\frac{\sigma}{2\alpha}$ and $q_b^{B*}=\frac{1}{2\alpha}$.

It is obvious from equations (B–11) and (B–12) that $p_b^B=p_e^B+\frac{1-\sigma^2}{4\alpha}$. Substituting this expression into equation (B–11), the implicit function of p_e^B can be derived such that

$$e^{p_e^B}\left(p_e^B-\frac{\sigma^2}{4\alpha}-1\right)=e^{\frac{\theta\sigma}{2\alpha}}+e^{\frac{1+\sigma^2}{4\alpha}}, \tag{B–13}$$

which concludes the proof. □

APPENDIX C
COMPLETE NUMERICAL RESULTS FOR THE CURRENT, ACCENTUATE AND ARCHITECT STRATEGIES: MONOPOLY CASE

			Profits			Green quality/brown quality			Total market share		
α	τ	θ	Base	Accentuate	Architect	Base	Accentuate	Architect	Base	Accentuate	Architect
0.2	2	0.2	0.6622	0.6630	0.7671	0	0.0080	0.0010	0.3984	0.3990	0.4341
	2	0.4	0.6622	0.6654	0.7672	0	0.0160	0.0019	0.3984	0.4007	0.4342
	2	0.6	0.6622	0.6694	0.7673	0	0.0242	0.0029	0.3984	0.4036	0.4342
	2	0.8	0.6622	0.6752	0.7675	0	0.0326	0.0039	0.3984	0.4078	0.4343
	2	1	0.6622	0.6828	0.7677	0	0.0413	0.0049	0.3984	0.4132	0.4345
	4	0.2	0.6622	0.6630	0.7671	0	0.0080	0.0006	0.3984	0.3990	0.4341
	4	0.4	0.6622	0.6654	0.7671	0	0.0160	0.0013	0.3984	0.4007	0.4341
	4	0.6	0.6622	0.6694	0.7672	0	0.0242	0.0019	0.3984	0.4036	0.4342
	4	0.8	0.6622	0.6752	0.7673	0	0.0326	0.0026	0.3984	0.4078	0.4343
	4	1	0.6622	0.6828	0.7675	0	0.0413	0.0032	0.3984	0.4132	0.4343
	6	0.2	0.6622	0.6630	0.7671	0	0.0080	0.0005	0.3984	0.3990	0.4341
	6	0.4	0.6622	0.6654	0.7671	0	0.0160	0.0010	0.3984	0.4007	0.4341
	6	0.6	0.6622	0.6694	0.7672	0	0.0242	0.0014	0.3984	0.4036	0.4342
	6	0.8	0.6622	0.6752	0.7673	0	0.0326	0.0019	0.3984	0.4078	0.4342
	6	1	0.6622	0.6828	0.7674	0	0.0413	0.0024	0.3984	0.4132	0.4343
	8	0.2	0.6622	0.6630	0.7671	0	0.0080	0.0004	0.3984	0.3990	0.4341
	8	0.4	0.6622	0.6654	0.7671	0	0.0160	0.0008	0.3984	0.4007	0.4341
	8	0.6	0.6622	0.6694	0.7672	0	0.0242	0.0012	0.3984	0.4036	0.4342
	8	0.8	0.6622	0.6752	0.7672	0	0.0326	0.0015	0.3984	0.4078	0.4342
	8	1	0.6622	0.6828	0.7673	0	0.0413	0.0019	0.3984	0.4132	0.4342
0.4	2	0.2	0.4418	0.4423	0.5868	0	0.0123	0.0025	0.3064	0.3069	0.3698
	2	0.4	0.4418	0.4437	0.5870	0	0.0247	0.0051	0.3064	0.3083	0.3699
	2	0.6	0.4418	0.4461	0.5872	0	0.0373	0.0077	0.3064	0.3106	0.3701
	2	0.8	0.4418	0.4495	0.5875	0	0.0502	0.0103	0.3064	0.3138	0.3703
	2	1	0.4418	0.4540	0.5878	0	0.0636	0.0129	0.3064	0.3182	0.3706
	4	0.2	0.4418	0.4423	0.5868	0	0.0123	0.0017	0.3064	0.3069	0.3698
	4	0.4	0.4418	0.4437	0.5869	0	0.0247	0.0034	0.3064	0.3083	0.3699
	4	0.6	0.4418	0.4461	0.5870	0	0.0373	0.0051	0.3064	0.3106	0.3700
	4	0.8	0.4418	0.4495	0.5872	0	0.0502	0.0069	0.3064	0.3138	0.3701
	4	1	0.4418	0.4540	0.5875	0	0.0636	0.0086	0.3064	0.3182	0.3703
	6	0.2	0.4418	0.4423	0.5868	0	0.0123	0.0013	0.3064	0.3069	0.3698
	6	0.4	0.4418	0.4437	0.5869	0	0.0247	0.0026	0.3064	0.3083	0.3699
	6	0.6	0.4418	0.4461	0.5870	0	0.0373	0.0039	0.3064	0.3106	0.3699
	6	0.8	0.4418	0.4495	0.5871	0	0.0502	0.0051	0.3064	0.3138	0.3701
	6	1	0.4418	0.4540	0.5873	0	0.0636	0.0064	0.3064	0.3182	0.3702
	8	0.2	0.4418	0.4423	0.5868	0	0.0123	0.0010	0.3064	0.3069	0.3698
	8	0.4	0.4418	0.4437	0.5869	0	0.0247	0.0021	0.3064	0.3083	0.3698
	8	0.6	0.4418	0.4461	0.5869	0	0.0373	0.0031	0.3064	0.3106	0.3699
	8	0.8	0.4418	0.4495	0.5871	0	0.0502	0.0041	0.3064	0.3138	0.3700
	8	1	0.4418	0.4540	0.5872	0	0.0636	0.0052	0.3064	0.3182	0.3701
0.6	2	0.2	0.3812	0.3816	0.5398	0	0.0166	0.0041	0.2760	0.2764	0.3506
	2	0.4	0.3812	0.3827	0.5399	0	0.0333	0.0082	0.2760	0.2776	0.3507
	2	0.6	0.3812	0.3846	0.5402	0	0.0503	0.0123	0.2760	0.2796	0.3509
	2	0.8	0.3812	0.3874	0.5405	0	0.0678	0.0165	0.2760	0.2825	0.3512
	2	1	0.3812	0.3911	0.5409	0	0.0859	0.0207	0.2760	0.2864	0.3515
	4	0.2	0.3812	0.3816	0.5398	0	0.0166	0.0027	0.2760	0.2764	0.3506
	4	0.4	0.3812	0.3827	0.5399	0	0.0333	0.0055	0.2760	0.2776	0.3506
	4	0.6	0.3812	0.3846	0.5400	0	0.0503	0.0083	0.2760	0.2796	0.3508
	4	0.8	0.3812	0.3874	0.5402	0	0.0678	0.0110	0.2760	0.2825	0.3510
	4	1	0.3812	0.3911	0.5405	0	0.0859	0.0139	0.2760	0.2864	0.3512

			Profits			Green quality/brown quality			Total market share		
α	τ	θ	Base	Accentuate	Architect	Base	Accentuate	Architect	Base	Accentuate	Architect
0.6	6	0.2	0.3812	0.3816	0.5397	0	0.0166	0.0021	0.2760	0.2764	0.3506
	6	0.4	0.3812	0.3827	0.5398	0	0.0333	0.0041	0.2760	0.2776	0.3506
	6	0.6	0.3812	0.3846	0.5399	0	0.0503	0.0062	0.2760	0.2796	0.3507
	6	0.8	0.3812	0.3874	0.5401	0	0.0678	0.0083	0.2760	0.2825	0.3509
	6	1	0.3812	0.3911	0.5403	0	0.0859	0.0104	0.2760	0.2864	0.3510
	8	0.2	0.3812	0.3816	0.5397	0	0.0166	0.0017	0.2760	0.2764	0.3505
	8	0.4	0.3812	0.3827	0.5398	0	0.0333	0.0033	0.2760	0.2776	0.3506
	8	0.6	0.3812	0.3846	0.5399	0	0.0503	0.0050	0.2760	0.2796	0.3507
	8	0.8	0.3812	0.3874	0.5400	0	0.0678	0.0067	0.2760	0.2825	0.3508
	8	1	0.3812	0.3911	0.5402	0	0.0859	0.0083	0.2760	0.2864	0.3509
0.8	2	0.2	0.3532	0.3535	0.5185	0	0.0209	0.0056	0.2610	0.2614	0.3415
	2	0.4	0.3532	0.3546	0.5187	0	0.0420	0.0112	0.2610	0.2625	0.3416
	2	0.6	0.3532	0.3563	0.5189	0	0.0635	0.0169	0.2610	0.2644	0.3418
	2	0.8	0.3532	0.3588	0.5193	0	0.0855	0.0226	0.2610	0.2671	0.3421
	2	1	0.3532	0.3620	0.5197	0	0.1083	0.0284	0.2610	0.2707	0.3425
	4	0.2	0.3532	0.3535	0.5185	0	0.0209	0.0038	0.2610	0.2614	0.3415
	4	0.4	0.3532	0.3546	0.5186	0	0.0420	0.0076	0.2610	0.2625	0.3416
	4	0.6	0.3532	0.3563	0.5188	0	0.0635	0.0114	0.2610	0.2644	0.3417
	4	0.8	0.3532	0.3588	0.5190	0	0.0855	0.0152	0.2610	0.2671	0.3419
	4	1	0.3532	0.3620	0.5193	0	0.1083	0.0190	0.2610	0.2707	0.3422
	6	0.2	0.3532	0.3535	0.5185	0	0.0209	0.0028	0.2610	0.2614	0.3415
	6	0.4	0.3532	0.3546	0.5186	0	0.0420	0.0057	0.2610	0.2625	0.3415
	6	0.6	0.3532	0.3563	0.5187	0	0.0635	0.0086	0.2610	0.2644	0.3416
	6	0.8	0.3532	0.3588	0.5189	0	0.0855	0.0114	0.2610	0.2671	0.3418
	6	1	0.3532	0.3620	0.5191	0	0.1083	0.0143	0.2610	0.2707	0.3420
	8	0.2	0.3532	0.3535	0.5185	0	0.0209	0.0023	0.2610	0.2614	0.3415
	8	0.4	0.3532	0.3546	0.5185	0	0.0420	0.0046	0.2610	0.2625	0.3415
	8	0.6	0.3532	0.3563	0.5186	0	0.0635	0.0069	0.2610	0.2644	0.3416
	8	0.8	0.3532	0.3588	0.5188	0	0.0855	0.0092	0.2610	0.2671	0.3417
	8	1	0.3532	0.3620	0.5190	0	0.1083	0.0115	0.2610	0.2707	0.3419
1.0	2	0.2	0.3372	0.3375	0.5064	0	0.0253	0.0071	0.2522	0.2525	0.3362
	2	0.4	0.3372	0.3384	0.5066	0	0.0507	0.0142	0.2522	0.2536	0.3363
	2	0.6	0.3372	0.3401	0.5069	0	0.0766	0.0214	0.2522	0.2554	0.3366
	2	0.8	0.3372	0.3424	0.5072	0	0.1032	0.0286	0.2522	0.2580	0.3369
	2	1	0.3372	0.3454	0.5077	0	0.1307	0.0359	0.2522	0.2614	0.3373
	4	0.2	0.3372	0.3375	0.5064	0	0.0253	0.0048	0.2522	0.2525	0.3362
	4	0.4	0.3372	0.3384	0.5065	0	0.0507	0.0096	0.2522	0.2536	0.3363
	4	0.6	0.3372	0.3401	0.5067	0	0.0766	0.0144	0.2522	0.2554	0.3364
	4	0.8	0.3372	0.3424	0.5070	0	0.1032	0.0193	0.2522	0.2580	0.3367
	4	1	0.3372	0.3454	0.5073	0	0.1307	0.0242	0.2522	0.2614	0.3369
	6	0.2	0.3372	0.3375	0.5064	0	0.0253	0.0036	0.2522	0.2525	0.3362
	6	0.4	0.3372	0.3384	0.5065	0	0.0507	0.0072	0.2522	0.2536	0.3363
	6	0.6	0.3372	0.3401	0.5066	0	0.0766	0.0109	0.2522	0.2554	0.3364
	6	0.8	0.3372	0.3424	0.5068	0	0.1032	0.0145	0.2522	0.2580	0.3365
	6	1	0.3372	0.3454	0.5071	0	0.1307	0.0182	0.2522	0.2614	0.3367
	8	0.2	0.3372	0.3375	0.5064	0	0.0253	0.0029	0.2522	0.2525	0.3362
	8	0.4	0.3372	0.3384	0.5065	0	0.0507	0.0058	0.2522	0.2536	0.3362
	8	0.6	0.3372	0.3401	0.5066	0	0.0766	0.0087	0.2522	0.2554	0.3363
	8	0.8	0.3372	0.3424	0.5067	0	0.1032	0.0116	0.2522	0.2580	0.3365
	8	1	0.3372	0.3454	0.5069	0	0.1307	0.0146	0.2522	0.2614	0.3366

APPENDIX D
PROOF OF LEMMA 1

The proof is by contradiction. Given that $\theta \in (0, 1]$ and $\gamma > 0$, suppose the value of Δ solving the equation

$$\Delta = e^{\left(-\frac{\theta^2}{\gamma(1+\Delta+\Delta^2)}+\frac{1}{\Delta}-\Delta\right)} \tag{D–1}$$

is greater than or equal to 1. Initially consider the case $\Delta = 1$. Substituting $\Delta = 1$ into the equation (D–1), it is obtained that

$$1 = e^{-\frac{\theta^2}{3\gamma}}, \tag{D–2}$$

which is satisfied if and only if $\theta = 0$. This is a contradiction, since $\theta > 0$. Secondly, suppose $\Delta > 1$. Then,

$$-\frac{\theta^2}{\gamma\left(1+\Delta+\Delta^2\right)}+\frac{1}{\Delta}-\Delta < 0, \tag{D–3}$$

meaning that

$$e^{\left(-\frac{\theta^2}{\gamma(1+\Delta+\Delta^2)}+\frac{1}{\Delta}-\Delta\right)} < 1. \tag{D–4}$$

Given that $e^{\left(-\frac{\theta^2}{\gamma(1+\Delta+\Delta^2)}+\frac{1}{\Delta}-\Delta\right)} = \Delta$ and $\Delta > 1$, this is a contradiction and so the proof follows. $\square$

APPENDIX E
COMPLETE NUMERICAL RESULTS FOR THE CURRENT VS ACCENTUATE STRATEGIES: DUOPOLY CASE

γ	θ	Δ	q_{e2}^{A}	$\hat{\Pi}_1^C$	$\hat{\Pi}_2^A$
	0.20	0.9989	0.0167	0.9989	1.0006
	0.40	0.9955	0.0335	0.9955	1.0022
4	0.60	0.9899	0.0505	0.9899	1.0051
	0.80	0.9821	0.0679	0.9821	1.0091
	1.00	0.9718	0.0857	0.9718	1.0143
	0.20	0.9993	0.0111	0.9993	1.0004
	0.40	0.9970	0.0223	0.9970	1.0015
6	0.60	0.9933	0.0336	0.9933	1.0034
	0.80	0.9881	0.0450	0.9881	1.0060
	1.00	0.9813	0.0566	0.9813	1.0094
	0.20	0.9994	0.0083	0.9994	1.0003
	0.40	0.9978	0.0167	0.9978	1.0011
8	0.60	0.9950	0.0251	0.9950	1.0025
	0.80	0.9911	0.0336	0.9911	1.0045
	1.00	0.9860	0.0423	0.9860	1.0070
	0.20	0.9996	0.0067	0.9996	1.0002
	0.40	0.9982	0.0134	0.9982	1.0009
10	0.60	0.9960	0.0201	0.9960	1.0020
	0.80	0.9929	0.0269	0.9929	1.0036
	1.00	0.9888	0.0337	0.9888	1.0056
	0.20	0.9998	0.0033	0.9998	1.0001
	0.40	0.9991	0.0067	0.9991	1.0004
20	0.60	0.9980	0.0100	0.9980	1.0010
	0.80	0.9964	0.0134	0.9964	1.0018
	1.00	0.9944	0.0168	0.9944	1.0028
	0.20	0.9999	0.0013	0.9999	1.0000
	0.40	0.9991	0.0042	0.9991	1.0004
50	0.60	0.9980	0.0063	0.9980	1.0010
	0.80	0.9964	0.0085	0.9964	1.0018
	1.00	0.9944	0.0106	0.9944	1.0028

APPENDIX F
COMPLETE NUMERICAL RESULTS FOR THE CURRENT VS ARCHITECT STRATEGIES: DUOPOLY CASE

τ	θ	Δ	q_{e2}^{B}	$\hat{\Pi}_1^C$	$\hat{\Pi}_2^B$
2	0.20	0.9195	0.0020	0.9195	1.0875
	0.40	0.9194	0.0040	0.9194	1.0876
	0.60	0.9193	0.0060	0.9193	1.0877
	0.80	0.9191	0.0081	0.9191	1.0878
	1.00	0.9188	0.0101	0.9188	1.0879
4	0.20	0.9195	0.0013	0.9195	1.0875
	0.40	0.9194	0.0027	0.9194	1.0876
	0.60	0.9193	0.0040	0.9193	1.0876
	0.80	0.9192	0.0054	0.9192	1.0877
	1.00	0.9191	0.0067	0.9191	1.0878
6	0.20	0.9195	0.0010	0.9195	1.0875
	0.40	0.9195	0.0020	0.9195	1.0876
	0.60	0.9194	0.0030	0.9194	1.0876
	0.80	0.9193	0.0040	0.9193	1.0877
	1.00	0.9192	0.0050	0.9192	1.0877
8	0.20	0.9195	0.0008	0.9195	1.0875
	0.40	0.9195	0.0016	0.9195	1.0876
	0.60	0.9194	0.0024	0.9194	1.0876
	0.80	0.9193	0.0032	0.9193	1.0876
	1.00	0.9192	0.0040	0.9192	1.0877
10	0.20	0.9195	0.0007	0.9195	1.0875
	0.40	0.9195	0.0013	0.9195	1.0876
	0.60	0.9194	0.0020	0.9194	1.0876
	0.80	0.9194	0.0027	0.9194	1.0876
	1.00	0.9193	0.0034	0.9193	1.0877
20	0.20	0.9195	0.0004	0.9195	1.0875
	0.40	0.9195	0.0007	0.9195	1.0875
	0.60	0.9195	0.0011	0.9195	1.0876
	0.80	0.9194	0.0015	0.9194	1.0876
	1.00	0.9194	0.0018	0.9194	1.0876

APPENDIX G
COMPLETE NUMERICAL RESULTS FOR THE ACCENTUATE AND ARCHITECT STRATEGIES: DUOPOLY CASE

γ	τ	θ	Δ	q_{e1}^A	q_{e2}^B	$\hat{\Pi}_1^A$	$\hat{\Pi}_2^B$
		0.20	0.9186	0.0153	0.0020	0.9181	1.0887
		0.40	0.9157	0.0304	0.0040	0.9138	1.0920
4	2	0.60	0.9110	0.0454	0.0060	0.9069	1.0976
		0.80	0.9045	0.0601	0.0081	0.8973	1.1053
		1.00	0.8964	0.0744	0.0101	0.8853	1.1152
		0.20	0.9186	0.0153	0.0013	0.9181	1.0886
		0.40	0.9157	0.0304	0.0027	0.9139	1.0920
4	4	0.60	0.9111	0.0454	0.0040	0.9069	1.0975
		0.80	0.9046	0.0601	0.0054	0.8974	1.1052
		1.00	0.8966	0.0744	0.0067	0.8855	1.1150
		0.20	0.9186	0.0153	0.0010	0.9181	1.0886
		0.40	0.9157	0.0304	0.0020	0.9139	1.0920
4	6	0.60	0.9111	0.0454	0.0030	0.9070	1.0975
		0.80	0.9047	0.0601	0.0040	0.8975	1.1052
		1.00	0.8967	0.0744	0.0050	0.8856	1.1150
		0.20	0.9186	0.0153	0.0007	0.9181	1.0886
		0.40	0.9158	0.0304	0.0016	0.9139	1.0920
4	8	0.60	0.9111	0.0454	0.0024	0.9070	1.0975
		0.80	0.9048	0.0601	0.0032	0.8975	1.1051
		1.00	0.8968	0.0744	0.0040	0.8857	1.1149
		0.20	0.9186	0.0153	0.0020	0.9181	1.0887
		0.40	0.9157	0.0304	0.0040	0.9138	1.0920
4	10	0.60	0.9110	0.0454	0.0060	0.9069	1.0976
		0.80	0.9045	0.0601	0.0081	0.8973	1.1053
		1.00	0.8964	0.0744	0.0101	0.8853	1.1152

γ	τ	θ	Δ	q_{e1}^{A}	q_{e2}^{B}	$\hat{\Pi}_1^A$	$\hat{\Pi}_2^B$
		0.20	0.9190	0.0076	0.0013	0.9188	1.0881
		0.40	0.9157	0.0304	0.0040	0.9138	1.0920
8	2	0.60	0.9110	0.0454	0.0060	0.9069	1.0976
		0.80	0.9045	0.0601	0.0081	0.8973	1.1053
		1.00	0.8964	0.0744	0.0101	0.8853	1.1152
		0.20	0.9190	0.0076	0.0010	0.9188	1.0881
		0.40	0.9157	0.0304	0.0027	0.9139	1.0920
8	4	0.60	0.9111	0.0454	0.0040	0.9069	1.0975
		0.80	0.9046	0.0601	0.0054	0.8974	1.1052
		1.00	0.8966	0.0744	0.0067	0.8855	1.1150
		0.20	0.9190	0.0076	0.0008	0.9188	1.0881
		0.40	0.9157	0.0304	0.0020	0.9139	1.0920
8	6	0.60	0.9111	0.0454	0.0030	0.9070	1.0975
		0.80	0.9047	0.0601	0.0040	0.8975	1.1052
		1.00	0.8967	0.0744	0.0050	0.8856	1.1150
		0.20	0.9190	0.0076	0.0007	0.9188	1.0881
		0.40	0.9158	0.0304	0.0016	0.9139	1.0920
8	8	0.60	0.9111	0.0454	0.0024	0.9070	1.0975
		0.80	0.9048	0.0601	0.0032	0.8975	1.1052
		1.00	0.8968	0.0744	0.0040	0.8857	1.1149
		0.20	0.9190	0.0076	0.0006	0.9188	1.0881
		0.40	0.9158	0.0304	0.0013	0.9139	1.0920
8	10	0.60	0.9111	0.0454	0.0020	0.9070	1.0975
		0.80	0.9048	0.0601	0.0027	0.8976	1.1051
		1.00	0.8968	0.0744	0.0034	0.8857	1.1149

γ	τ	θ	Δ	q_{e1}^{A}	q_{e2}^{B}	$\hat{\Pi}_1^A$	$\hat{\Pi}_2^B$
		0.20	0.9192	0.0051	0.0010	0.9190	1.0879
		0.40	0.9157	0.0304	0.0040	0.9138	1.0920
12	2	0.60	0.9110	0.0454	0.0060	0.9069	1.0976
		0.80	0.9045	0.0601	0.0081	0.8973	1.1053
		1.00	0.8964	0.0744	0.0101	0.8853	1.1152
		0.20	0.9190	0.0076	0.0008	0.9187	1.0881
		0.40	0.9157	0.0304	0.0027	0.9139	1.0920
12	4	0.60	0.9111	0.0454	0.0040	0.9069	1.0975
		0.80	0.9046	0.0601	0.0054	0.8974	1.1052
		1.00	0.8966	0.0744	0.0067	0.8855	1.1150
		0.20	0.9190	0.0076	0.0007	0.9187	1.0881
		0.40	0.9157	0.0304	0.0020	0.9139	1.0920
12	6	0.60	0.9111	0.0454	0.0030	0.9070	1.0975
		0.80	0.9047	0.0601	0.0040	0.8975	1.1052
		1.00	0.8967	0.0744	0.0050	0.8856	1.1150
		0.20	0.9190	0.0076	0.0006	0.9187	1.0881
		0.40	0.9158	0.0304	0.0016	0.9139	1.0920
12	8	0.60	0.9111	0.0454	0.0024	0.9070	1.0975
		0.80	0.9048	0.0601	0.0032	0.8975	1.1052
		1.00	0.8968	0.0744	0.0040	0.8857	1.1149
		0.20	0.9190	0.0076	0.0005	0.9187	1.0881
		0.40	0.9158	0.0304	0.0013	0.9139	1.0920
12	10	0.60	0.9111	0.0454	0.0020	0.9070	1.0975
		0.80	0.9048	0.0601	0.0027	0.8976	1.1051
		1.00	0.8968	0.0744	0.0034	0.8857	1.1149

APPENDIX H
COMPLETE NUMERICAL RESULTS FOR THE GREENING OFF, GREENING OUT AND GREENING OUT STRATEGIES

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	4	0.1	4	20	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.2	4	20	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.3	4	20	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.4	4	20	0.52	0.33	0.15	34.0	-0.8	5.9	1.6	2.0
8	4	0.5	4	20	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.6	4	20	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.7	4	20	0.52	0.33	0.15	34.0	-0.7	0.0	2.3	0.0
8	4	0.8	4	20	0.52	0.33	0.15	34.0	0.3	0.0	2.7	0.0
8	4	0.9	4	20	0.52	0.33	0.15	34.0	1.4	0.0	3.0	0.0
8	4	1	4	20	0.52	0.33	0.15	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	20	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.2	12	20	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.3	12	20	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.4	12	20	0.52	0.33	0.15	34.0	-8.8	5.9	1.6	2.0
8	4	0.5	12	20	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.6	12	20	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.7	12	20	0.52	0.33	0.15	34.0	-8.7	0.0	2.3	0.0
8	4	0.8	12	20	0.52	0.33	0.15	34.0	-7.7	0.0	2.7	0.0
8	4	0.9	12	20	0.52	0.33	0.15	34.0	-6.6	0.0	3.0	0.0
8	4	1	12	20	0.52	0.33	0.15	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	20	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.2	24	20	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.3	24	20	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.4	24	20	0.52	0.33	0.15	34.0	-20.8	5.9	1.6	2.0
8	4	0.5	24	20	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.6	24	20	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.7	24	20	0.52	0.33	0.15	34.0	-20.7	0.0	2.3	0.0
8	4	0.8	24	20	0.52	0.33	0.15	34.0	-19.7	0.0	2.7	0.0
8	4	0.9	24	20	0.52	0.33	0.15	34.0	-18.6	0.0	3.0	0.0
8	4	1	24	20	0.52	0.33	0.15	40.0	-17.3	0.0	3.3	0.0
8	4	0.1	4	40	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.2	4	40	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.3	4	40	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.4	4	40	0.52	0.33	0.15	34.0	-0.8	5.5	1.6	1.0
8	4	0.5	4	40	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.6	4	40	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.7	4	40	0.52	0.33	0.15	34.0	-0.7	0.0	2.3	0.0
8	4	0.8	4	40	0.52	0.33	0.15	34.0	0.3	0.0	2.7	0.0
8	4	0.9	4	40	0.52	0.33	0.15	34.0	1.4	0.0	3.0	0.0
8	4	1	4	40	0.52	0.33	0.15	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	40	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.2	12	40	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.3	12	40	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.4	12	40	0.52	0.33	0.15	34.0	-8.8	5.5	1.6	1.0
8	4	0.5	12	40	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.6	12	40	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.7	12	40	0.52	0.33	0.15	34.0	-8.7	0.0	2.3	0.0
8	4	0.8	12	40	0.52	0.33	0.15	34.0	-7.7	0.0	2.7	0.0
8	4	0.9	12	40	0.52	0.33	0.15	34.0	-6.6	0.0	3.0	0.0
8	4	1	12	40	0.52	0.33	0.15	40.0	-5.3	0.0	3.3	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	4	0.1	24	40	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.2	24	40	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.3	24	40	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.4	24	40	0.52	0.33	0.15	34.0	-20.8	5.5	1.6	1.0
8	4	0.5	24	40	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.6	24	40	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.7	24	40	0.52	0.33	0.15	34.0	-20.7	0.0	2.3	0.0
8	4	0.8	24	40	0.52	0.33	0.15	34.0	-19.7	0.0	2.7	0.0
8	4	0.9	24	40	0.52	0.33	0.15	34.0	-18.6	0.0	3.0	0.0
8	4	1	24	40	0.52	0.33	0.15	40.0	-17.3	0.0	3.3	0.0
8	4	0.1	4	60	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.2	4	60	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.3	4	60	0.52	0.33	0.15	34.0	-0.8	3.9	1.6	1.3
8	4	0.4	4	60	0.52	0.33	0.15	34.0	-0.8	5.4	1.6	0.7
8	4	0.5	4	60	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.6	4	60	0.52	0.33	0.15	34.0	-0.8	0.0	1.6	0.0
8	4	0.7	4	60	0.52	0.33	0.15	34.0	-0.7	0.0	2.3	0.0
8	4	0.8	4	60	0.52	0.33	0.15	34.0	0.3	0.0	2.7	0.0
8	4	0.9	4	60	0.52	0.33	0.15	34.0	1.4	0.0	3.0	0.0
8	4	1	4	60	0.52	0.33	0.15	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	60	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.2	12	60	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.3	12	60	0.52	0.33	0.15	34.0	-8.8	3.9	1.6	1.3
8	4	0.4	12	60	0.52	0.33	0.15	34.0	-8.8	5.4	1.6	0.7
8	4	0.5	12	60	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.6	12	60	0.52	0.33	0.15	34.0	-8.8	0.0	1.6	0.0
8	4	0.7	12	60	0.52	0.33	0.15	34.0	-8.7	0.0	2.3	0.0
8	4	0.8	12	60	0.52	0.33	0.15	34.0	-7.7	0.0	2.7	0.0
8	4	0.9	12	60	0.52	0.33	0.15	34.0	-6.6	0.0	3.0	0.0
8	4	1	12	60	0.52	0.33	0.15	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	60	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.2	24	60	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.3	24	60	0.52	0.33	0.15	34.0	-20.8	3.9	1.6	1.3
8	4	0.4	24	60	0.52	0.33	0.15	34.0	-20.8	5.4	1.6	0.7
8	4	0.5	24	60	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.6	24	60	0.52	0.33	0.15	34.0	-20.8	0.0	1.6	0.0
8	4	0.7	24	60	0.52	0.33	0.15	34.0	-20.7	0.0	2.3	0.0
8	4	0.8	24	60	0.52	0.33	0.15	34.0	-19.7	0.0	2.7	0.0
8	4	0.9	24	60	0.52	0.33	0.15	34.0	-18.6	0.0	3.0	0.0
8	4	1	24	60	0.52	0.33	0.15	40.0	-17.3	0.0	3.3	0.0
8	8	0.1	4	20	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.2	4	20	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.3	4	20	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.4	4	20	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.5	4	20	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.6	4	20	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.7	4	20	0.52	0.33	0.15	34.0	9.1	0.0	4.7	0.0
8	8	0.8	4	20	0.52	0.33	0.15	34.0	13.1	0.0	5.3	0.0
8	8	0.9	4	20	0.52	0.33	0.15	34.0	17.6	26.7	6.0	2.0
8	8	1	4	20	0.52	0.33	0.15	40.0	22.7	0.0	6.7	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	8	0.1	12	20	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.2	12	20	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.3	12	20	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.4	12	20	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.5	12	20	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.6	12	20	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.7	12	20	0.52	0.33	0.15	34.0	1.1	0.0	4.7	0.0
8	8	0.8	12	20	0.52	0.33	0.15	34.0	5.1	0.0	5.3	0.0
8	8	0.9	12	20	0.52	0.33	0.15	34.0	9.6	26.7	6.0	2.0
8	8	1	12	20	0.52	0.33	0.15	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	20	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.2	24	20	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.3	24	20	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.4	24	20	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.5	24	20	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.6	24	20	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.7	24	20	0.52	0.33	0.15	34.0	-10.9	0.0	4.7	0.0
8	8	0.8	24	20	0.52	0.33	0.15	34.0	-6.9	0.0	5.3	0.0
8	8	0.9	24	20	0.52	0.33	0.15	34.0	-2.4	26.7	6.0	2.0
8	8	1	24	20	0.52	0.33	0.15	40.0	2.7	0.0	6.7	0.0
8	8	0.1	4	40	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.2	4	40	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.3	4	40	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.4	4	40	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.5	4	40	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.6	4	40	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.7	4	40	0.52	0.33	0.15	34.0	9.1	0.0	4.7	0.0
8	8	0.8	4	40	0.52	0.33	0.15	34.0	13.1	22.1	5.3	2.0
8	8	0.9	4	40	0.52	0.33	0.15	34.0	17.6	26.3	6.0	1.0
8	8	1	4	40	0.52	0.33	0.15	40.0	22.7	0.0	6.7	0.0
8	8	0.1	12	40	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.2	12	40	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.3	12	40	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.4	12	40	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.5	12	40	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.6	12	40	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.7	12	40	0.52	0.33	0.15	34.0	1.1	0.0	4.7	0.0
8	8	0.8	12	40	0.52	0.33	0.15	34.0	5.1	22.1	5.3	2.0
8	8	0.9	12	40	0.52	0.33	0.15	34.0	9.6	26.3	6.0	1.0
8	8	1	12	40	0.52	0.33	0.15	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	40	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.2	24	40	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.3	24	40	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.4	24	40	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.5	24	40	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.6	24	40	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.7	24	40	0.52	0.33	0.15	34.0	-10.9	0.0	4.7	0.0
8	8	0.8	24	40	0.52	0.33	0.15	34.0	-6.9	22.1	5.3	2.0
8	8	0.9	24	40	0.52	0.33	0.15	34.0	-2.4	26.3	6.0	1.0
8	8	1	24	40	0.52	0.33	0.15	40.0	2.7	0.0	6.7	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	8	0.1	4	60	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.2	4	60	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.3	4	60	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.4	4	60	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.5	4	60	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.6	4	60	0.52	0.33	0.15	34.0	8.8	0.0	3.2	0.0
8	8	0.7	4	60	0.52	0.33	0.15	34.0	9.1	18.1	4.7	2.0
8	8	0.8	4	60	0.52	0.33	0.15	34.0	13.1	21.5	5.3	1.3
8	8	0.9	4	60	0.52	0.33	0.15	34.0	17.6	26.2	6.0	0.7
8	8	1	4	60	0.52	0.33	0.15	40.0	22.7	0.0	6.7	0.0
8	8	0.1	12	60	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.2	12	60	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.3	12	60	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.4	12	60	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.5	12	60	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.6	12	60	0.52	0.33	0.15	34.0	0.8	0.0	3.2	0.0
8	8	0.7	12	60	0.52	0.33	0.15	34.0	1.1	18.1	4.7	2.0
8	8	0.8	12	60	0.52	0.33	0.15	34.0	5.1	21.5	5.3	1.3
8	8	0.9	12	60	0.52	0.33	0.15	34.0	9.6	26.2	6.0	0.7
8	8	1	12	60	0.52	0.33	0.15	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	60	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.2	24	60	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.3	24	60	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.4	24	60	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.5	24	60	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.6	24	60	0.52	0.33	0.15	34.0	-11.2	0.0	3.2	0.0
8	8	0.7	24	60	0.52	0.33	0.15	34.0	-10.9	18.1	4.7	2.0
8	8	0.8	24	60	0.52	0.33	0.15	34.0	-6.9	21.5	5.3	1.3
8	8	0.9	24	60	0.52	0.33	0.15	34.0	-2.4	26.2	6.0	0.7
8	8	1	24	60	0.52	0.33	0.15	40.0	2.7	0.0	6.7	0.0
8	16	0.1	4	20	0.52	0.33	0.15	34.0	47.2	19.3	6.4	2.2
8	16	0.2	4	20	0.52	0.33	0.15	34.0	47.2	19.3	6.4	2.2
8	16	0.3	4	20	0.52	0.33	0.15	34.0	47.2	19.3	6.4	2.2
8	16	0.4	4	20	0.52	0.33	0.15	34.0	47.2	19.3	6.4	2.2
8	16	0.5	4	20	0.52	0.33	0.15	34.0	47.2	19.3	6.4	2.2
8	16	0.6	4	20	0.52	0.33	0.15	34.0	47.2	35.2	6.4	4.0
8	16	0.7	4	20	0.52	0.33	0.15	34.0	48.3	44.8	9.3	8.0
8	16	0.8	4	20	0.52	0.33	0.15	34.0	64.3	19.3	10.7	2.2
8	16	0.9	4	20	0.52	0.33	0.15	34.0	82.4	19.3	12.0	2.2
8	16	1	4	20	0.52	0.33	0.15	40.0	102.7	19.3	13.3	2.2
8	16	0.1	12	20	0.52	0.33	0.15	34.0	39.2	19.3	6.4	2.2
8	16	0.2	12	20	0.52	0.33	0.15	34.0	39.2	19.3	6.4	2.2
8	16	0.3	12	20	0.52	0.33	0.15	34.0	39.2	19.3	6.4	2.2
8	16	0.4	12	20	0.52	0.33	0.15	34.0	39.2	19.3	6.4	2.2
8	16	0.5	12	20	0.52	0.33	0.15	34.0	39.2	19.3	6.4	2.2
8	16	0.6	12	20	0.52	0.33	0.15	34.0	39.2	35.2	6.4	4.0
8	16	0.7	12	20	0.52	0.33	0.15	34.0	40.3	44.8	9.3	8.0
8	16	0.8	12	20	0.52	0.33	0.15	34.0	56.3	19.3	10.7	2.2
8	16	0.9	12	20	0.52	0.33	0.15	34.0	74.4	19.3	12.0	2.2
8	16	1	12	20	0.52	0.33	0.15	40.0	94.7	19.3	13.3	2.2

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	16	0.1	24	20	0.52	0.33	0.15	34.0	27.2	19.3	6.4	2.2
8	16	0.2	24	20	0.52	0.33	0.15	34.0	27.2	19.3	6.4	2.2
8	16	0.3	24	20	0.52	0.33	0.15	34.0	27.2	19.3	6.4	2.2
8	16	0.4	24	20	0.52	0.33	0.15	34.0	27.2	19.3	6.4	2.2
8	16	0.5	24	20	0.52	0.33	0.15	34.0	27.2	19.3	6.4	2.2
8	16	0.6	24	20	0.52	0.33	0.15	34.0	27.2	35.2	6.4	4.0
8	16	0.7	24	20	0.52	0.33	0.15	34.0	28.3	44.8	9.3	8.0
8	16	0.8	24	20	0.52	0.33	0.15	34.0	44.3	19.3	10.7	2.2
8	16	0.9	24	20	0.52	0.33	0.15	34.0	62.4	19.3	12.0	2.2
8	16	1	24	20	0.52	0.33	0.15	40.0	82.7	19.3	13.3	2.2
8	16	0.1	4	40	0.52	0.33	0.15	34.0	47.2	14.9	6.4	1.1
8	16	0.2	4	40	0.52	0.33	0.15	34.0	47.2	14.9	6.4	1.1
8	16	0.3	4	40	0.52	0.33	0.15	34.0	47.2	14.9	6.4	1.1
8	16	0.4	4	40	0.52	0.33	0.15	34.0	47.2	14.9	6.4	1.1
8	16	0.5	4	40	0.52	0.33	0.15	34.0	47.2	14.9	6.4	1.1
8	16	0.6	4	40	0.52	0.33	0.15	34.0	47.2	14.9	6.4	1.1
8	16	0.7	4	40	0.52	0.33	0.15	34.0	48.3	38.4	9.3	4.0
8	16	0.8	4	40	0.52	0.33	0.15	34.0	64.3	46.4	10.7	6.0
8	16	0.9	4	40	0.52	0.33	0.15	34.0	82.4	14.9	12.0	1.1
8	16	1	4	40	0.52	0.33	0.15	40.0	102.7	14.9	13.3	1.1
8	16	0.1	12	40	0.52	0.33	0.15	34.0	39.2	14.9	6.4	1.1
8	16	0.2	12	40	0.52	0.33	0.15	34.0	39.2	14.9	6.4	1.1
8	16	0.3	12	40	0.52	0.33	0.15	34.0	39.2	14.9	6.4	1.1
8	16	0.4	12	40	0.52	0.33	0.15	34.0	39.2	14.9	6.4	1.1
8	16	0.5	12	40	0.52	0.33	0.15	34.0	39.2	14.9	6.4	1.1
8	16	0.6	12	40	0.52	0.33	0.15	34.0	39.2	14.9	6.4	1.1
8	16	0.7	12	40	0.52	0.33	0.15	34.0	40.3	38.4	9.3	4.0
8	16	0.8	12	40	0.52	0.33	0.15	34.0	56.3	46.4	10.7	6.0
8	16	0.9	12	40	0.52	0.33	0.15	34.0	74.4	14.9	12.0	1.1
8	16	1	12	40	0.52	0.33	0.15	40.0	94.7	14.9	13.3	1.1
8	16	0.1	24	40	0.52	0.33	0.15	34.0	27.2	14.9	6.4	1.1
8	16	0.2	24	40	0.52	0.33	0.15	34.0	27.2	14.9	6.4	1.1
8	16	0.3	24	40	0.52	0.33	0.15	34.0	27.2	14.9	6.4	1.1
8	16	0.4	24	40	0.52	0.33	0.15	34.0	27.2	14.9	6.4	1.1
8	16	0.5	24	40	0.52	0.33	0.15	34.0	27.2	14.9	6.4	1.1
8	16	0.6	24	40	0.52	0.33	0.15	34.0	27.2	14.9	6.4	1.1
8	16	0.7	24	40	0.52	0.33	0.15	34.0	28.3	38.4	9.3	4.0
8	16	0.8	24	40	0.52	0.33	0.15	34.0	44.3	46.4	10.7	6.0
8	16	0.9	24	40	0.52	0.33	0.15	34.0	62.4	14.9	12.0	1.1
8	16	1	24	40	0.52	0.33	0.15	40.0	82.7	14.9	13.3	1.1
8	16	0.1	4	60	0.52	0.33	0.15	34.0	47.2	13.5	6.4	0.7
8	16	0.2	4	60	0.52	0.33	0.15	34.0	47.2	13.5	6.4	0.7
8	16	0.3	4	60	0.52	0.33	0.15	34.0	47.2	13.5	6.4	0.7
8	16	0.4	4	60	0.52	0.33	0.15	34.0	47.2	13.5	6.4	0.7
8	16	0.5	4	60	0.52	0.33	0.15	34.0	47.2	13.5	6.4	0.7
8	16	0.6	4	60	0.52	0.33	0.15	34.0	47.2	13.5	6.4	0.7
8	16	0.7	4	60	0.52	0.33	0.15	34.0	48.3	36.3	9.3	2.7
8	16	0.8	4	60	0.52	0.33	0.15	34.0	64.3	41.6	10.7	4.0
8	16	0.9	4	60	0.52	0.33	0.15	34.0	82.4	49.1	12.0	5.3
8	16	1	4	60	0.52	0.33	0.15	40.0	102.7	58.7	13.3	6.7

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	16	0.1	12	60	0.52	0.33	0.15	34.0	39.2	13.5	6.4	0.7
8	16	0.2	12	60	0.52	0.33	0.15	34.0	39.2	13.5	6.4	0.7
8	16	0.3	12	60	0.52	0.33	0.15	34.0	39.2	13.5	6.4	0.7
8	16	0.4	12	60	0.52	0.33	0.15	34.0	39.2	13.5	6.4	0.7
8	16	0.5	12	60	0.52	0.33	0.15	34.0	39.2	13.5	6.4	0.7
8	16	0.6	12	60	0.52	0.33	0.15	34.0	39.2	13.5	6.4	0.7
8	16	0.7	12	60	0.52	0.33	0.15	34.0	40.3	36.3	9.3	2.7
8	16	0.8	12	60	0.52	0.33	0.15	34.0	56.3	41.6	10.7	4.0
8	16	0.9	12	60	0.52	0.33	0.15	34.0	74.4	49.1	12.0	5.3
8	16	1	12	60	0.52	0.33	0.15	40.0	94.7	58.7	13.3	6.7
8	16	0.1	24	60	0.52	0.33	0.15	34.0	27.2	13.5	6.4	0.7
8	16	0.2	24	60	0.52	0.33	0.15	34.0	27.2	13.5	6.4	0.7
8	16	0.3	24	60	0.52	0.33	0.15	34.0	27.2	13.5	6.4	0.7
8	16	0.4	24	60	0.52	0.33	0.15	34.0	27.2	13.5	6.4	0.7
8	16	0.5	24	60	0.52	0.33	0.15	34.0	27.2	13.5	6.4	0.7
8	16	0.6	24	60	0.52	0.33	0.15	34.0	27.2	13.5	6.4	0.7
8	16	0.7	24	60	0.52	0.33	0.15	34.0	28.3	36.3	9.3	2.7
8	16	0.8	24	60	0.52	0.33	0.15	34.0	44.3	41.6	10.7	4.0
8	16	0.9	24	60	0.52	0.33	0.15	34.0	62.4	49.1	12.0	5.3
8	16	1	24	60	0.52	0.33	0.15	40.0	82.7	58.7	13.3	6.7
8	4	0.1	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.2	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.3	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.4	4	20	0.33	0.33	0.33	26.7	0.4	5.9	2.2	2.0
8	4	0.5	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.6	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.7	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.8	4	20	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.9	4	20	0.33	0.33	0.33	32.4	1.4	0.0	3.0	0.0
8	4	1	4	20	0.33	0.33	0.33	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.2	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.3	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.4	12	20	0.33	0.33	0.33	26.7	-7.6	5.9	2.2	2.0
8	4	0.5	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.6	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.7	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.8	12	20	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.9	12	20	0.33	0.33	0.33	32.4	-6.6	0.0	3.0	0.0
8	4	1	12	20	0.33	0.33	0.33	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.2	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.3	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.4	24	20	0.33	0.33	0.33	26.7	-19.6	5.9	2.2	2.0
8	4	0.5	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.6	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.7	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.8	24	20	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.9	24	20	0.33	0.33	0.33	32.4	-18.6	0.0	3.0	0.0
8	4	1	24	20	0.33	0.33	0.33	40.0	-17.3	0.0	3.3	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	4	0.1	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.2	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.3	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.4	4	40	0.33	0.33	0.33	26.7	0.4	5.5	2.2	1.0
8	4	0.5	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.6	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.7	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.8	4	40	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.9	4	40	0.33	0.33	0.33	32.4	1.4	0.0	3.0	0.0
8	4	1	4	40	0.33	0.33	0.33	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.2	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.3	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.4	12	40	0.33	0.33	0.33	26.7	-7.6	5.5	2.2	1.0
8	4	0.5	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.6	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.7	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.8	12	40	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.9	12	40	0.33	0.33	0.33	32.4	-6.6	0.0	3.0	0.0
8	4	1	12	40	0.33	0.33	0.33	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.2	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.3	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.4	24	40	0.33	0.33	0.33	26.7	-19.6	5.5	2.2	1.0
8	4	0.5	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.6	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.7	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.8	24	40	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.9	24	40	0.33	0.33	0.33	32.4	-18.6	0.0	3.0	0.0
8	4	1	24	40	0.33	0.33	0.33	40.0	-17.3	0.0	3.3	0.0
8	4	0.1	4	60	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.2	4	60	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.3	4	60	0.33	0.33	0.33	26.7	0.4	3.9	2.2	1.3
8	4	0.4	4	60	0.33	0.33	0.33	26.7	0.4	5.4	2.2	0.7
8	4	0.5	4	60	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.6	4	60	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.7	4	60	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.8	4	60	0.33	0.33	0.33	26.7	0.4	0.0	2.2	0.0
8	4	0.9	4	60	0.33	0.33	0.33	32.4	1.4	0.0	3.0	0.0
8	4	1	4	60	0.33	0.33	0.33	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	60	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.2	12	60	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.3	12	60	0.33	0.33	0.33	26.7	-7.6	3.9	2.2	1.3
8	4	0.4	12	60	0.33	0.33	0.33	26.7	-7.6	5.4	2.2	0.7
8	4	0.5	12	60	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.6	12	60	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.7	12	60	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.8	12	60	0.33	0.33	0.33	26.7	-7.6	0.0	2.2	0.0
8	4	0.9	12	60	0.33	0.33	0.33	32.4	-6.6	0.0	3.0	0.0
8	4	1	12	60	0.33	0.33	0.33	40.0	-5.3	0.0	3.3	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	4	0.1	24	60	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.2	24	60	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.3	24	60	0.33	0.33	0.33	26.7	-19.6	3.9	2.2	1.3
8	4	0.4	24	60	0.33	0.33	0.33	26.7	-19.6	5.4	2.2	0.7
8	4	0.5	24	60	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.6	24	60	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.7	24	60	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.8	24	60	0.33	0.33	0.33	26.7	-19.6	0.0	2.2	0.0
8	4	0.9	24	60	0.33	0.33	0.33	32.4	-18.6	0.0	3.0	0.0
8	4	1	24	60	0.33	0.33	0.33	40.0	-17.3	0.0	3.3	0.0
8	8	0.1	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.2	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.3	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.4	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.5	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.6	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.7	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.8	4	20	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.9	4	20	0.33	0.33	0.33	32.4	17.6	26.7	6.0	2.0
8	8	1	4	20	0.33	0.33	0.33	40.0	22.7	0.0	6.7	0.0
8	8	0.1	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.2	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.3	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.4	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.5	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.6	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.7	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.8	12	20	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.9	12	20	0.33	0.33	0.33	32.4	9.6	26.7	6.0	2.0
8	8	1	12	20	0.33	0.33	0.33	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.2	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.3	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.4	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.5	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.6	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.7	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.8	24	20	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.9	24	20	0.33	0.33	0.33	32.4	-2.4	26.7	6.0	2.0
8	8	1	24	20	0.33	0.33	0.33	40.0	2.7	0.0	6.7	0.0
8	8	0.1	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.2	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.3	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.4	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.5	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.6	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.7	4	40	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.8	4	40	0.33	0.33	0.33	26.7	13.8	22.1	4.4	2.0
8	8	0.9	4	40	0.33	0.33	0.33	32.4	17.6	26.3	6.0	1.0
8	8	1	4	40	0.33	0.33	0.33	40.0	22.7	0.0	6.7	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	8	0.1	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.2	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.3	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.4	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.5	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.6	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.7	12	40	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.8	12	40	0.33	0.33	0.33	26.7	5.8	22.1	4.4	2.0
8	8	0.9	12	40	0.33	0.33	0.33	32.4	9.6	26.3	6.0	1.0
8	8	1	12	40	0.33	0.33	0.33	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.2	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.3	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.4	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.5	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.6	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.7	24	40	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.8	24	40	0.33	0.33	0.33	26.7	-6.2	22.1	4.4	2.0
8	8	0.9	24	40	0.33	0.33	0.33	32.4	-2.4	26.3	6.0	1.0
8	8	1	24	40	0.33	0.33	0.33	40.0	2.7	0.0	6.7	0.0
8	8	0.1	4	60	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.2	4	60	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.3	4	60	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.4	4	60	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.5	4	60	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.6	4	60	0.33	0.33	0.33	26.7	13.8	0.0	4.4	0.0
8	8	0.7	4	60	0.33	0.33	0.33	26.7	13.8	18.1	4.4	2.0
8	8	0.8	4	60	0.33	0.33	0.33	26.7	13.8	21.5	4.4	1.3
8	8	0.9	4	60	0.33	0.33	0.33	32.4	17.6	26.2	6.0	0.7
8	8	1	4	60	0.33	0.33	0.33	40.0	22.7	0.0	6.7	0.0
8	8	0.1	12	60	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.2	12	60	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.3	12	60	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.4	12	60	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.5	12	60	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.6	12	60	0.33	0.33	0.33	26.7	5.8	0.0	4.4	0.0
8	8	0.7	12	60	0.33	0.33	0.33	26.7	5.8	18.1	4.4	2.0
8	8	0.8	12	60	0.33	0.33	0.33	26.7	5.8	21.5	4.4	1.3
8	8	0.9	12	60	0.33	0.33	0.33	32.4	9.6	26.2	6.0	0.7
8	8	1	12	60	0.33	0.33	0.33	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	60	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.2	24	60	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.3	24	60	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.4	24	60	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.5	24	60	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.6	24	60	0.33	0.33	0.33	26.7	-6.2	0.0	4.4	0.0
8	8	0.7	24	60	0.33	0.33	0.33	26.7	-6.2	18.1	4.4	2.0
8	8	0.8	24	60	0.33	0.33	0.33	26.7	-6.2	21.5	4.4	1.3
8	8	0.9	24	60	0.33	0.33	0.33	32.4	-2.4	26.2	6.0	0.7
8	8	1	24	60	0.33	0.33	0.33	40.0	2.7	0.0	6.7	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	16	0.1	4	20	0.33	0.33	0.33	26.7	67.1	19.6	8.9	2.2
8	16	0.2	4	20	0.33	0.33	0.33	26.7	67.1	19.6	8.9	2.2
8	16	0.3	4	20	0.33	0.33	0.33	26.7	67.1	19.6	8.9	2.2
8	16	0.4	4	20	0.33	0.33	0.33	26.7	67.1	19.6	8.9	2.2
8	16	0.5	4	20	0.33	0.33	0.33	26.7	67.1	19.6	8.9	2.2
8	16	0.6	4	20	0.33	0.33	0.33	26.7	67.1	35.2	8.9	4.0
8	16	0.7	4	20	0.33	0.33	0.33	26.7	67.1	44.8	8.9	8.0
8	16	0.8	4	20	0.33	0.33	0.33	26.7	67.1	19.6	8.9	2.2
8	16	0.9	4	20	0.33	0.33	0.33	32.4	82.4	19.6	12.0	2.2
8	16	1	4	20	0.33	0.33	0.33	40.0	102.7	19.6	13.3	2.2
8	16	0.1	12	20	0.33	0.33	0.33	26.7	59.1	19.6	8.9	2.2
8	16	0.2	12	20	0.33	0.33	0.33	26.7	59.1	19.6	8.9	2.2
8	16	0.3	12	20	0.33	0.33	0.33	26.7	59.1	19.6	8.9	2.2
8	16	0.4	12	20	0.33	0.33	0.33	26.7	59.1	19.6	8.9	2.2
8	16	0.5	12	20	0.33	0.33	0.33	26.7	59.1	19.6	8.9	2.2
8	16	0.6	12	20	0.33	0.33	0.33	26.7	59.1	35.2	8.9	4.0
8	16	0.7	12	20	0.33	0.33	0.33	26.7	59.1	44.8	8.9	8.0
8	16	0.8	12	20	0.33	0.33	0.33	26.7	59.1	19.6	8.9	2.2
8	16	0.9	12	20	0.33	0.33	0.33	32.4	74.4	19.6	12.0	2.2
8	16	1	12	20	0.33	0.33	0.33	40.0	94.7	19.6	13.3	2.2
8	16	0.1	24	20	0.33	0.33	0.33	26.7	47.1	19.6	8.9	2.2
8	16	0.2	24	20	0.33	0.33	0.33	26.7	47.1	19.6	8.9	2.2
8	16	0.3	24	20	0.33	0.33	0.33	26.7	47.1	19.6	8.9	2.2
8	16	0.4	24	20	0.33	0.33	0.33	26.7	47.1	19.6	8.9	2.2
8	16	0.5	24	20	0.33	0.33	0.33	26.7	47.1	19.6	8.9	2.2
8	16	0.6	24	20	0.33	0.33	0.33	26.7	47.1	35.2	8.9	4.0
8	16	0.7	24	20	0.33	0.33	0.33	26.7	47.1	44.8	8.9	8.0
8	16	0.8	24	20	0.33	0.33	0.33	26.7	47.1	19.6	8.9	2.2
8	16	0.9	24	20	0.33	0.33	0.33	32.4	62.4	19.6	12.0	2.2
8	16	1	24	20	0.33	0.33	0.33	40.0	82.7	19.6	13.3	2.2
8	16	0.1	4	40	0.33	0.33	0.33	26.7	67.1	15.1	8.9	1.1
8	16	0.2	4	40	0.33	0.33	0.33	26.7	67.1	15.1	8.9	1.1
8	16	0.3	4	40	0.33	0.33	0.33	26.7	67.1	15.1	8.9	1.1
8	16	0.4	4	40	0.33	0.33	0.33	26.7	67.1	15.1	8.9	1.1
8	16	0.5	4	40	0.33	0.33	0.33	26.7	67.1	15.1	8.9	1.1
8	16	0.6	4	40	0.33	0.33	0.33	26.7	67.1	15.1	8.9	1.1
8	16	0.7	4	40	0.33	0.33	0.33	26.7	67.1	38.4	8.9	4.0
8	16	0.8	4	40	0.33	0.33	0.33	26.7	67.1	46.4	8.9	6.0
8	16	0.9	4	40	0.33	0.33	0.33	32.4	82.4	15.1	12.0	1.1
8	16	1	4	40	0.33	0.33	0.33	40.0	102.7	15.1	13.3	1.1
8	16	0.1	12	40	0.33	0.33	0.33	26.7	59.1	15.1	8.9	1.1
8	16	0.2	12	40	0.33	0.33	0.33	26.7	59.1	15.1	8.9	1.1
8	16	0.3	12	40	0.33	0.33	0.33	26.7	59.1	15.1	8.9	1.1
8	16	0.4	12	40	0.33	0.33	0.33	26.7	59.1	15.1	8.9	1.1
8	16	0.5	12	40	0.33	0.33	0.33	26.7	59.1	15.1	8.9	1.1
8	16	0.6	12	40	0.33	0.33	0.33	26.7	59.1	15.1	8.9	1.1
8	16	0.7	12	40	0.33	0.33	0.33	26.7	59.1	38.4	8.9	4.0
8	16	0.8	12	40	0.33	0.33	0.33	26.7	59.1	46.4	8.9	6.0
8	16	0.9	12	40	0.33	0.33	0.33	32.4	74.4	15.1	12.0	1.1
8	16	1	12	40	0.33	0.33	0.33	40.0	94.7	15.1	13.3	1.1

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	16	0.1	24	40	0.33	0.33	0.33	26.7	47.1	15.1	8.9	1.1
8	16	0.2	24	40	0.33	0.33	0.33	26.7	47.1	15.1	8.9	1.1
8	16	0.3	24	40	0.33	0.33	0.33	26.7	47.1	15.1	8.9	1.1
8	16	0.4	24	40	0.33	0.33	0.33	26.7	47.1	15.1	8.9	1.1
8	16	0.5	24	40	0.33	0.33	0.33	26.7	47.1	15.1	8.9	1.1
8	16	0.6	24	40	0.33	0.33	0.33	26.7	47.1	15.1	8.9	1.1
8	16	0.7	24	40	0.33	0.33	0.33	26.7	47.1	38.4	8.9	4.0
8	16	0.8	24	40	0.33	0.33	0.33	26.7	47.1	46.4	8.9	6.0
8	16	0.9	24	40	0.33	0.33	0.33	32.4	62.4	15.1	12.0	1.1
8	16	1	24	40	0.33	0.33	0.33	40.0	82.7	15.1	13.3	1.1
8	16	0.1	4	60	0.33	0.33	0.33	26.7	67.1	13.6	8.9	0.7
8	16	0.2	4	60	0.33	0.33	0.33	26.7	67.1	13.6	8.9	0.7
8	16	0.3	4	60	0.33	0.33	0.33	26.7	67.1	13.6	8.9	0.7
8	16	0.4	4	60	0.33	0.33	0.33	26.7	67.1	13.6	8.9	0.7
8	16	0.5	4	60	0.33	0.33	0.33	26.7	67.1	13.6	8.9	0.7
8	16	0.6	4	60	0.33	0.33	0.33	26.7	67.1	13.6	8.9	0.7
8	16	0.7	4	60	0.33	0.33	0.33	26.7	67.1	36.3	8.9	2.7
8	16	0.8	4	60	0.33	0.33	0.33	26.7	67.1	41.6	8.9	4.0
8	16	0.9	4	60	0.33	0.33	0.33	32.4	82.4	49.1	12.0	5.3
8	16	1	4	60	0.33	0.33	0.33	40.0	102.7	58.7	13.3	6.7
8	16	0.1	12	60	0.33	0.33	0.33	26.7	59.1	13.6	8.9	0.7
8	16	0.2	12	60	0.33	0.33	0.33	26.7	59.1	13.6	8.9	0.7
8	16	0.3	12	60	0.33	0.33	0.33	26.7	59.1	13.6	8.9	0.7
8	16	0.4	12	60	0.33	0.33	0.33	26.7	59.1	13.6	8.9	0.7
8	16	0.5	12	60	0.33	0.33	0.33	26.7	59.1	13.6	8.9	0.7
8	16	0.6	12	60	0.33	0.33	0.33	26.7	59.1	13.6	8.9	0.7
8	16	0.7	12	60	0.33	0.33	0.33	26.7	59.1	36.3	8.9	2.7
8	16	0.8	12	60	0.33	0.33	0.33	26.7	59.1	41.6	8.9	4.0
8	16	0.9	12	60	0.33	0.33	0.33	32.4	74.4	49.1	12.0	5.3
8	16	1	12	60	0.33	0.33	0.33	40.0	94.7	58.7	13.3	6.7
8	16	0.1	24	60	0.33	0.33	0.33	26.7	47.1	13.6	8.9	0.7
8	16	0.2	24	60	0.33	0.33	0.33	26.7	47.1	13.6	8.9	0.7
8	16	0.3	24	60	0.33	0.33	0.33	26.7	47.1	13.6	8.9	0.7
8	16	0.4	24	60	0.33	0.33	0.33	26.7	47.1	13.6	8.9	0.7
8	16	0.5	24	60	0.33	0.33	0.33	26.7	47.1	13.6	8.9	0.7
8	16	0.6	24	60	0.33	0.33	0.33	26.7	47.1	13.6	8.9	0.7
8	16	0.7	24	60	0.33	0.33	0.33	26.7	47.1	36.3	8.9	2.7
8	16	0.8	24	60	0.33	0.33	0.33	26.7	47.1	41.6	8.9	4.0
8	16	0.9	24	60	0.33	0.33	0.33	32.4	62.4	49.1	12.0	5.3
8	16	1	24	60	0.33	0.33	0.33	40.0	82.7	58.7	13.3	6.7
8	4	0.1	4	20	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.2	4	20	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.3	4	20	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.4	4	20	0.15	0.33	0.52	19.2	1.7	5.9	2.8	2.0
8	4	0.5	4	20	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.6	4	20	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.7	4	20	0.15	0.33	0.52	19.6	1.7	0.0	2.8	0.0
8	4	0.8	4	20	0.15	0.33	0.52	25.6	1.7	0.0	2.8	0.0
8	4	0.9	4	20	0.15	0.33	0.52	32.4	1.7	0.0	2.8	0.0
8	4	1	4	20	0.15	0.33	0.52	40.0	2.7	0.0	3.3	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	4	0.1	12	20	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.2	12	20	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.3	12	20	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.4	12	20	0.15	0.33	0.52	19.2	-6.3	5.9	2.8	2.0
8	4	0.5	12	20	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.6	12	20	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.7	12	20	0.15	0.33	0.52	19.6	-6.3	0.0	2.8	0.0
8	4	0.8	12	20	0.15	0.33	0.52	25.6	-6.3	0.0	2.8	0.0
8	4	0.9	12	20	0.15	0.33	0.52	32.4	-6.3	0.0	2.8	0.0
8	4	1	12	20	0.15	0.33	0.52	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	20	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.2	24	20	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.3	24	20	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.4	24	20	0.15	0.33	0.52	19.2	-18.3	5.9	2.8	2.0
8	4	0.5	24	20	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.6	24	20	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.7	24	20	0.15	0.33	0.52	19.6	-18.3	0.0	2.8	0.0
8	4	0.8	24	20	0.15	0.33	0.52	25.6	-18.3	0.0	2.8	0.0
8	4	0.9	24	20	0.15	0.33	0.52	32.4	-18.3	0.0	2.8	0.0
8	4	1	24	20	0.15	0.33	0.52	40.0	-17.3	0.0	3.3	0.0
8	4	0.1	4	40	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.2	4	40	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.3	4	40	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.4	4	40	0.15	0.33	0.52	19.2	1.7	5.5	2.8	1.0
8	4	0.5	4	40	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.6	4	40	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.7	4	40	0.15	0.33	0.52	19.6	1.7	0.0	2.8	0.0
8	4	0.8	4	40	0.15	0.33	0.52	25.6	1.7	0.0	2.8	0.0
8	4	0.9	4	40	0.15	0.33	0.52	32.4	1.7	0.0	2.8	0.0
8	4	1	4	40	0.15	0.33	0.52	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	40	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.2	12	40	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.3	12	40	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.4	12	40	0.15	0.33	0.52	19.2	-6.3	5.5	2.8	1.0
8	4	0.5	12	40	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.6	12	40	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.7	12	40	0.15	0.33	0.52	19.6	-6.3	0.0	2.8	0.0
8	4	0.8	12	40	0.15	0.33	0.52	25.6	-6.3	0.0	2.8	0.0
8	4	0.9	12	40	0.15	0.33	0.52	32.4	-6.3	0.0	2.8	0.0
8	4	1	12	40	0.15	0.33	0.52	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	40	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.2	24	40	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.3	24	40	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.4	24	40	0.15	0.33	0.52	19.2	-18.3	5.5	2.8	1.0
8	4	0.5	24	40	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.6	24	40	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.7	24	40	0.15	0.33	0.52	19.6	-18.3	0.0	2.8	0.0
8	4	0.8	24	40	0.15	0.33	0.52	25.6	-18.3	0.0	2.8	0.0
8	4	0.9	24	40	0.15	0.33	0.52	32.4	-18.3	0.0	2.8	0.0
8	4	1	24	40	0.15	0.33	0.52	40.0	-17.3	0.0	3.3	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	4	0.1	4	60	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.2	4	60	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.3	4	60	0.15	0.33	0.52	19.2	1.7	3.9	2.8	1.3
8	4	0.4	4	60	0.15	0.33	0.52	19.2	1.7	5.4	2.8	0.7
8	4	0.5	4	60	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.6	4	60	0.15	0.33	0.52	19.2	1.7	0.0	2.8	0.0
8	4	0.7	4	60	0.15	0.33	0.52	19.6	1.7	0.0	2.8	0.0
8	4	0.8	4	60	0.15	0.33	0.52	25.6	1.7	0.0	2.8	0.0
8	4	0.9	4	60	0.15	0.33	0.52	32.4	1.7	0.0	2.8	0.0
8	4	1	4	60	0.15	0.33	0.52	40.0	2.7	0.0	3.3	0.0
8	4	0.1	12	60	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.2	12	60	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.3	12	60	0.15	0.33	0.52	19.2	-6.3	3.9	2.8	1.3
8	4	0.4	12	60	0.15	0.33	0.52	19.2	-6.3	5.4	2.8	0.7
8	4	0.5	12	60	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.6	12	60	0.15	0.33	0.52	19.2	-6.3	0.0	2.8	0.0
8	4	0.7	12	60	0.15	0.33	0.52	19.6	-6.3	0.0	2.8	0.0
8	4	0.8	12	60	0.15	0.33	0.52	25.6	-6.3	0.0	2.8	0.0
8	4	0.9	12	60	0.15	0.33	0.52	32.4	-6.3	0.0	2.8	0.0
8	4	1	12	60	0.15	0.33	0.52	40.0	-5.3	0.0	3.3	0.0
8	4	0.1	24	60	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.2	24	60	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.3	24	60	0.15	0.33	0.52	19.2	-18.3	3.9	2.8	1.3
8	4	0.4	24	60	0.15	0.33	0.52	19.2	-18.3	5.4	2.8	0.7
8	4	0.5	24	60	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.6	24	60	0.15	0.33	0.52	19.2	-18.3	0.0	2.8	0.0
8	4	0.7	24	60	0.15	0.33	0.52	19.6	-18.3	0.0	2.8	0.0
8	4	0.8	24	60	0.15	0.33	0.52	25.6	-18.3	0.0	2.8	0.0
8	4	0.9	24	60	0.15	0.33	0.52	32.4	-18.3	0.0	2.8	0.0
8	4	1	24	60	0.15	0.33	0.52	40.0	-17.3	0.0	3.3	0.0
8	8	0.1	4	20	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.2	4	20	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.3	4	20	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.4	4	20	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.5	4	20	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.6	4	20	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.7	4	20	0.15	0.33	0.52	19.6	18.7	0.0	5.7	0.0
8	8	0.8	4	20	0.15	0.33	0.52	25.6	18.7	0.0	5.7	0.0
8	8	0.9	4	20	0.15	0.33	0.52	32.4	18.7	26.7	5.7	2.0
8	8	1	4	20	0.15	0.33	0.52	40.0	22.7	0.0	6.7	0.0
8	8	0.1	12	20	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.2	12	20	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.3	12	20	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.4	12	20	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.5	12	20	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.6	12	20	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.7	12	20	0.15	0.33	0.52	19.6	10.7	0.0	5.7	0.0
8	8	0.8	12	20	0.15	0.33	0.52	25.6	10.7	0.0	5.7	0.0
8	8	0.9	12	20	0.15	0.33	0.52	32.4	10.7	26.7	5.7	2.0
8	8	1	12	20	0.15	0.33	0.52	40.0	14.7	0.0	6.7	0.0

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	8	0.1	24	20	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.2	24	20	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.3	24	20	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.4	24	20	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.5	24	20	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.6	24	20	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.7	24	20	0.15	0.33	0.52	19.6	-1.3	0.0	5.7	0.0
8	8	0.8	24	20	0.15	0.33	0.52	25.6	-1.3	0.0	5.7	0.0
8	8	0.9	24	20	0.15	0.33	0.52	32.4	-1.3	26.7	5.7	2.0
8	8	1	24	20	0.15	0.33	0.52	40.0	2.7	0.0	6.7	0.0
8	8	0.1	4	40	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.2	4	40	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.3	4	40	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.4	4	40	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.5	4	40	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.6	4	40	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.7	4	40	0.15	0.33	0.52	19.6	18.7	0.0	5.7	0.0
8	8	0.8	4	40	0.15	0.33	0.52	25.6	18.7	22.1	5.7	2.0
8	8	0.9	4	40	0.15	0.33	0.52	32.4	18.7	26.3	5.7	1.0
8	8	1	4	40	0.15	0.33	0.52	40.0	22.7	0.0	6.7	0.0
8	8	0.1	12	40	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.2	12	40	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.3	12	40	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.4	12	40	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.5	12	40	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.6	12	40	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.7	12	40	0.15	0.33	0.52	19.6	10.7	0.0	5.7	0.0
8	8	0.8	12	40	0.15	0.33	0.52	25.6	10.7	22.1	5.7	2.0
8	8	0.9	12	40	0.15	0.33	0.52	32.4	10.7	26.3	5.7	1.0
8	8	1	12	40	0.15	0.33	0.52	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	40	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.2	24	40	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.3	24	40	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.4	24	40	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.5	24	40	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.6	24	40	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.7	24	40	0.15	0.33	0.52	19.6	-1.3	0.0	5.7	0.0
8	8	0.8	24	40	0.15	0.33	0.52	25.6	-1.3	22.1	5.7	2.0
8	8	0.9	24	40	0.15	0.33	0.52	32.4	-1.3	26.3	5.7	1.0
8	8	1	24	40	0.15	0.33	0.52	40.0	2.7	0.0	6.7	0.0
8	8	0.1	4	60	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.2	4	60	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.3	4	60	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.4	4	60	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.5	4	60	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.6	4	60	0.15	0.33	0.52	19.2	18.7	0.0	5.7	0.0
8	8	0.7	4	60	0.15	0.33	0.52	19.6	18.7	18.1	5.7	2.0
8	8	0.8	4	60	0.15	0.33	0.52	25.6	18.7	21.5	5.7	1.3
8	8	0.9	4	60	0.15	0.33	0.52	32.4	18.7	26.2	5.7	0.7
8	8	1	4	60	0.15	0.33	0.52	40.0	22.7	0.0	6.7	0.0

v_t	v_e	θ	N	F	r_B	r_F	r_G	Profits Greening-Off	Profits Greening-Out	Profits Greening-Up	TEQ Greening-Out	TEQ Greening-Up
8	8	0.1	12	60	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.2	12	60	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.3	12	60	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.4	12	60	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.5	12	60	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.6	12	60	0.15	0.33	0.52	19.2	10.7	0.0	5.7	0.0
8	8	0.7	12	60	0.15	0.33	0.52	19.6	10.7	18.1	5.7	2.0
8	8	0.8	12	60	0.15	0.33	0.52	25.6	10.7	21.5	5.7	1.3
8	8	0.9	12	60	0.15	0.33	0.52	32.4	10.7	26.2	5.7	0.7
8	8	1	12	60	0.15	0.33	0.52	40.0	14.7	0.0	6.7	0.0
8	8	0.1	24	60	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.2	24	60	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.3	24	60	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.4	24	60	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.5	24	60	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.6	24	60	0.15	0.33	0.52	19.2	-1.3	0.0	5.7	0.0
8	8	0.7	24	60	0.15	0.33	0.52	19.6	-1.3	18.1	5.7	2.0
8	8	0.8	24	60	0.15	0.33	0.52	25.6	-1.3	21.5	5.7	1.3
8	8	0.9	24	60	0.15	0.33	0.52	32.4	-1.3	26.2	5.7	0.7
8	8	1	24	60	0.15	0.33	0.52	40.0	2.7	0.0	6.7	0.0
8	16	0.1	4	20	0.15	0.33	0.52	19.2	86.7	19.3	11.3	2.2
8	16	0.2	4	20	0.15	0.33	0.52	19.2	86.7	19.3	11.3	2.2
8	16	0.3	4	20	0.15	0.33	0.52	19.2	86.7	19.3	11.3	2.2
8	16	0.4	4	20	0.15	0.33	0.52	19.2	86.7	19.3	11.3	2.2
8	16	0.5	4	20	0.15	0.33	0.52	19.2	86.7	19.3	11.3	2.2
8	16	0.6	4	20	0.15	0.33	0.52	19.2	86.7	35.2	11.3	4.0
8	16	0.7	4	20	0.15	0.33	0.52	19.6	86.7	44.8	11.3	8.0
8	16	0.8	4	20	0.15	0.33	0.52	25.6	86.7	19.3	11.3	2.2
8	16	0.9	4	20	0.15	0.33	0.52	32.4	86.7	19.3	11.3	2.2
8	16	1	4	20	0.15	0.33	0.52	40.0	102.7	19.3	13.3	2.2
8	16	0.1	12	20	0.15	0.33	0.52	19.2	78.7	19.3	11.3	2.2
8	16	0.2	12	20	0.15	0.33	0.52	19.2	78.7	19.3	11.3	2.2
8	16	0.3	12	20	0.15	0.33	0.52	19.2	78.7	19.3	11.3	2.2
8	16	0.4	12	20	0.15	0.33	0.52	19.2	78.7	19.3	11.3	2.2
8	16	0.5	12	20	0.15	0.33	0.52	19.2	78.7	19.3	11.3	2.2
8	16	0.6	12	20	0.15	0.33	0.52	19.2	78.7	35.2	11.3	4.0
8	16	0.7	12	20	0.15	0.33	0.52	19.6	78.7	44.8	11.3	8.0
8	16	0.8	12	20	0.15	0.33	0.52	25.6	78.7	19.3	11.3	2.2
8	16	0.9	12	20	0.15	0.33	0.52	32.4	78.7	19.3	11.3	2.2
8	16	1	12	20	0.15	0.33	0.52	40.0	94.7	19.3	13.3	2.2
8	16	0.1	24	20	0.15	0.33	0.52	19.2	66.7	19.3	11.3	2.2
8	16	0.2	24	20	0.15	0.33	0.52	19.2	66.7	19.3	11.3	2.2
8	16	0.3	24	20	0.15	0.33	0.52	19.2	66.7	19.3	11.3	2.2
8	16	0.4	24	20	0.15	0.33	0.52	19.2	66.7	19.3	11.3	2.2
8	16	0.5	24	20	0.15	0.33	0.52	19.2	66.7	19.3	11.3	2.2
8	16	0.6	24	20	0.15	0.33	0.52	19.2	66.7	35.2	11.3	4.0
8	16	0.7	24	20	0.15	0.33	0.52	19.6	66.7	44.8	11.3	8.0
8	16	0.8	24	20	0.15	0.33	0.52	25.6	66.7	19.3	11.3	2.2
8	16	0.9	24	20	0.15	0.33	0.52	32.4	66.7	19.3	11.3	2.2
8	16	1	24	20	0.15	0.33	0.52	40.0	82.7	19.3	13.3	2.2

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	16	0.1	4	40	0.15	0.33	0.52	19.2	86.7	14.9	11.3	1.1
8	16	0.2	4	40	0.15	0.33	0.52	19.2	86.7	14.9	11.3	1.1
8	16	0.3	4	40	0.15	0.33	0.52	19.2	86.7	14.9	11.3	1.1
8	16	0.4	4	40	0.15	0.33	0.52	19.2	86.7	14.9	11.3	1.1
8	16	0.5	4	40	0.15	0.33	0.52	19.2	86.7	14.9	11.3	1.1
8	16	0.6	4	40	0.15	0.33	0.52	19.2	86.7	14.9	11.3	1.1
8	16	0.7	4	40	0.15	0.33	0.52	19.6	86.7	38.4	11.3	4.0
8	16	0.8	4	40	0.15	0.33	0.52	25.6	86.7	46.4	11.3	6.0
8	16	0.9	4	40	0.15	0.33	0.52	32.4	86.7	14.9	11.3	1.1
8	16	1	4	40	0.15	0.33	0.52	40.0	102.7	14.9	13.3	1.1
8	16	0.1	12	40	0.15	0.33	0.52	19.2	78.7	14.9	11.3	1.1
8	16	0.2	12	40	0.15	0.33	0.52	19.2	78.7	14.9	11.3	1.1
8	16	0.3	12	40	0.15	0.33	0.52	19.2	78.7	14.9	11.3	1.1
8	16	0.4	12	40	0.15	0.33	0.52	19.2	78.7	14.9	11.3	1.1
8	16	0.5	12	40	0.15	0.33	0.52	19.2	78.7	14.9	11.3	1.1
8	16	0.6	12	40	0.15	0.33	0.52	19.2	78.7	14.9	11.3	1.1
8	16	0.7	12	40	0.15	0.33	0.52	19.6	78.7	38.4	11.3	4.0
8	16	0.8	12	40	0.15	0.33	0.52	25.6	78.7	46.4	11.3	6.0
8	16	0.9	12	40	0.15	0.33	0.52	32.4	78.7	14.9	11.3	1.1
8	16	1	12	40	0.15	0.33	0.52	40.0	94.7	14.9	13.3	1.1
8	16	0.1	24	40	0.15	0.33	0.52	19.2	66.7	14.9	11.3	1.1
8	16	0.2	24	40	0.15	0.33	0.52	19.2	66.7	14.9	11.3	1.1
8	16	0.3	24	40	0.15	0.33	0.52	19.2	66.7	14.9	11.3	1.1
8	16	0.4	24	40	0.15	0.33	0.52	19.2	66.7	14.9	11.3	1.1
8	16	0.5	24	40	0.15	0.33	0.52	19.2	66.7	14.9	11.3	1.1
8	16	0.6	24	40	0.15	0.33	0.52	19.2	66.7	14.9	11.3	1.1
8	16	0.7	24	40	0.15	0.33	0.52	19.6	66.7	38.4	11.3	4.0
8	16	0.8	24	40	0.15	0.33	0.52	25.6	66.7	46.4	11.3	6.0
8	16	0.9	24	40	0.15	0.33	0.52	32.4	66.7	14.9	11.3	1.1
8	16	1	24	40	0.15	0.33	0.52	40.0	82.7	14.9	13.3	1.1
8	16	0.1	4	60	0.15	0.33	0.52	19.2	86.7	13.5	11.3	0.7
8	16	0.2	4	60	0.15	0.33	0.52	19.2	86.7	13.5	11.3	0.7
8	16	0.3	4	60	0.15	0.33	0.52	19.2	86.7	13.5	11.3	0.7
8	16	0.4	4	60	0.15	0.33	0.52	19.2	86.7	13.5	11.3	0.7
8	16	0.5	4	60	0.15	0.33	0.52	19.2	86.7	13.5	11.3	0.7
8	16	0.6	4	60	0.15	0.33	0.52	19.2	86.7	13.5	11.3	0.7
8	16	0.7	4	60	0.15	0.33	0.52	19.6	86.7	36.3	11.3	2.7
8	16	0.8	4	60	0.15	0.33	0.52	25.6	86.7	41.6	11.3	4.0
8	16	0.9	4	60	0.15	0.33	0.52	32.4	86.7	49.1	11.3	5.3
8	16	1	4	60	0.15	0.33	0.52	40.0	102.7	58.7	13.3	6.7
8	16	0.1	12	60	0.15	0.33	0.52	19.2	78.7	13.5	11.3	0.7
8	16	0.2	12	60	0.15	0.33	0.52	19.2	78.7	13.5	11.3	0.7
8	16	0.3	12	60	0.15	0.33	0.52	19.2	78.7	13.5	11.3	0.7
8	16	0.4	12	60	0.15	0.33	0.52	19.2	78.7	13.5	11.3	0.7
8	16	0.5	12	60	0.15	0.33	0.52	19.2	78.7	13.5	11.3	0.7
8	16	0.6	12	60	0.15	0.33	0.52	19.2	78.7	13.5	11.3	0.7
8	16	0.7	12	60	0.15	0.33	0.52	19.6	78.7	36.3	11.3	2.7
8	16	0.8	12	60	0.15	0.33	0.52	25.6	78.7	41.6	11.3	4.0
8	16	0.9	12	60	0.15	0.33	0.52	32.4	78.7	49.1	11.3	5.3
8	16	1	12	60	0.15	0.33	0.52	40.0	94.7	58.7	13.3	6.7

								Profits			TEQ	
v_t	v_e	θ	N	F	r_B	r_F	r_G	Greening-Off	Greening-Out	Greening-Up	Greening-Out	Greening-Up
8	16	0.1	24	60	0.15	0.33	0.52	19.2	66.7	13.5	11.3	0.7
8	16	0.2	24	60	0.15	0.33	0.52	19.2	66.7	13.5	11.3	0.7
8	16	0.3	24	60	0.15	0.33	0.52	19.2	66.7	13.5	11.3	0.7
8	16	0.4	24	60	0.15	0.33	0.52	19.2	66.7	13.5	11.3	0.7
8	16	0.5	24	60	0.15	0.33	0.52	19.2	66.7	13.5	11.3	0.7
8	16	0.6	24	60	0.15	0.33	0.52	19.2	66.7	13.5	11.3	0.7
8	16	0.7	24	60	0.15	0.33	0.52	19.6	66.7	36.3	11.3	2.7
8	16	0.8	24	60	0.15	0.33	0.52	25.6	66.7	41.6	11.3	4.0
8	16	0.9	24	60	0.15	0.33	0.52	32.4	66.7	49.1	11.3	5.3
8	16	1	24	60	0.15	0.33	0.52	40.0	82.7	58.7	13.3	6.7

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