THREE ESSAYS ON PRODUCT DIFFERENTIATION AND STRATEGY

By

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I dedicate this dissertation to Mom and Dad. My work is their work.

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The first chapter considers a vertically differentiated products market, in which consumers internalize the environmental harm caused by the products they consume. A brown incumbent falsely represents its product as more green than it actually is. Consumers' beliefs regarding the harm caused by consuming the incumbents variant determine whether a greener entrant can profitably enter the market. Greenwash by the incumbent firm serves profitably to increase its own market share, but it may also have important implications for the market structure. I show that 1) consumers benefit from false advertising when entry is not deterred, and when consumers are able to correctly identify the incumbents variant as the dirtier product; 2) reductions in the fixed cost of entry always benefit consumers; 3) entry always increases the aggregate amount of environmental harm; and 4) reductions in the fixed cost of entry always harm the environment. These results may inform market regulators and environmental groups that wish to combat (or facilitate) false advertising by polluting firms.

The second chapter considers concert ticket bundling. Music concert tickets as well as many other admission-based events are often sold in bundles, and the existing literature does not adequately address the composition of an optimal bundle this setting. This chapter decomposes substitutability of component events into both the degree of horizontal differentiation between components and the additivity of consumers preferences across them. It considers a monopoly setting in which two

component events may be offered separately or as a pure bundle (i.e., mixed bundling is treated as infeasible). The chapter considers both the optimal pricing and bundling strategy when the degree of differentiation between the components is exogenously determined and the construction of the optimal bundle when the degree of differentiation may be selected by the monopolist. I find that, in terms of the degree of horizontal differentiation between the components, very similar and very different components are sold separately, whereas moderately differentiated components are offered as a bundle. I also demonstrate that capacity constraints affect the incentive to bundle reducing (intensifying) it when the constraint applies to unbundled components separately (jointly). Moreover, capacity constraints decrease the level of differentiation between bundled components. Lastly, I find that duopolists offer more similar events separately than a monopolist would optimally offer as a bundle.

The third chapter explores the effect of horizontal mergers on product quality, paying particular attention to the case of hospital combinations. I examine the role that market concentration and the proximity of merging hospitals plays in determining post-merger quality adjustments and welfare effects. Consumers are uniformly distributed along a Hotelling line, as are N hospitals. Initially, the N hospitals first select location, and then, set service quality and prices simultaneously. After two of the hospitals merge, all hospitals can adjust service quality and prices, but locations remain fixed at their pre-merger placements. I show that 1) mergers between two neighboring hospitals always reduce service quality; 2) mergers between two hospitals that are only separated by one hospital between them result in increased service quality and consumer welfare; 3) mergers between two hospitals that are separated by two or more hospitals between them do not increase the profits of merging hospitals; and 4) mergers between two hospitals that are separated by two of more hospitals between them do not affect service quality or consumer welfare.

CHAPTER 1
DETERRING THE GREEN REVOLUTION: GREENWASH AND THE THREAT OF GREEN ENTRY

1.1 Introduction

Claims of various products' environmental friendliness have become commonplace. Organic produce, shade-grown coffee, and "lead-free" toys offer familiar examples of attempts by firms to convey environmental friendliness to consumers. Not surprisingly, the rise in green-based advertising accompanies a marked rise in consumers' willingness to pay for environmentally friendly products. Both the provision of information by firms and the internalization of environmental externalities by consumers should enhance market efficiency and reduce environmental harm, but they also give rise to new issues of concern. Do firms have the incentive to make honest claims about their products, and are the lies they might tell necessarily bad?

False claims of environmental friendliness or stewardship - commonly referred to as "greenwash" - mislead consumers and dupe them into paying elevated prices for "brown" products, or even buying "brown" products that they otherwise would not have purchased. Greenwash is a strategic tool employed by firms to mislead consumers and cheaply increase the demand for their products. Deceitfully increasing the demand for a product through false claims of elevated quality allows firms to charge higher prices and earn supranormal profits without actually making costly quality improvements. Reducing false environmental claims should, at first glance, be considered socially desirable. For these reasons, the FTC seeks to limit such deceptive practices.

Section 5 of the Federal Trade Commission Act (FTC Act) prohibits "unfair or deceptive acts or practices in or affecting commerce" and makes the Federal Trade Commission (FTC) responsible for monitoring and punishing false advertising claims. In response to a sharp rise in environment-related claims, last year, the FTC issued "Guides for the Use of Environmental Marketing Claims." These comprehensive guidelines provide the agency's interpretation of Section 5 of the FTC Act, as it applies

to green advertising. They offer a glimpse at what practices the agency is likely to challenge. While these thorough guidelines advocate for scientifically verifiable and specific claims, they cannot be considered exhaustive. They simply address the most common practices in green advertising; more nuanced cases are to be addressed by the commission at its own discretion. As the agency moves forward and decides what cases to take up, it should be informed of the incentives that its behavior affects and the likely outcomes of fighting false green advertising claims. This paper explores the effects of environmental marketing and highlights a number of important issues that should be considered by an enforcement agency. It characterizes the effect of greenwash advertising on consumer surplus and aggregate environmental harm.

The following sections present and analyze a multi-stage game, in which two firms each produce one variant of a differentiated product, each indexed by the exogenously assigned level of environmental harm it yields. A brown incumbent produces a variant that is harmful to the environment, and a green potential entrant produces a less harmful variant. Before the green firm decides to enter, the brown incumbent may undertake false advertising to convince consumers that its variant is less harmful that it actually is. [1] The remainder of this paper is organized as follows: Section 2 proceeds with a brief survey of the recent literature on greenwash and green entry, Section 3 presents and solves a theoretical model of greenwash by a brown incumbent when it faces the threat of entry by a greener rival, and finally, Section 4 presents the effects of greenwash on consumer welfare and aggregate environmental harm, and Section 5 provides some brief concluding remarks.

[1] The model presented in this paper treats the polluting product as a credence good, assuming that neither consumers nor the green potential entrant can observe the incumbent‘s actual level of harm ex post.

1.2 Previous Literature

Increasingly, economic inquiries related to polluting products treat the products' environmental effects as dimensions of vertical differentiation, as opposed to the traditional externalities-based treatment. This relatively new view of environmental harm presents new issues related to strategic behavior, as environmental harm becomes incorporated into the payoffs and incentives of economic agents. This paper considers the role that false advertising plays in determining market structure and environmental harm. This section places this paper in context, by presenting a brief review of two strings of current research. First, this section identifies a new approach to analyzing polluting firms and their products, one based on vertical differentiation. This section also identifies an emerging literature related to false advertising and its effect on market efficiency, paying particular attention to polluting products.[2] Below, each of these two strings of literature is brought together, in an attempt to place this paper appropriately in context and demonstrate its contribution.

The first string of relevant literature develops the vertical differentiation approach to polluting products. Many recent theoretical studies of polluting products and environmental harm utilize a model of vertically differentiated products, originally introduced by Arora and Gangopadhyay (1995) and further developed by Cremer and Thisse (1999) and Motta and Thisse (1999). For example, Heijen (2007) employs a vertical differentiation approach similar to that in Cremer and Thisse (1999). He examines the role of environmental groups that conduct informative advertising campaigns. He finds that when firms cannot choose their level of harm, the environmental group advertises against dirty firms. When firms can choose their level of environmental harm, simply the threat of the environmental group is enough to make dirty firms reduce their environmental harm. Heijen and Schoonbeek (2008) obtain a similar result to

[2] For an extensive survey of the advertising literature, see Bagwell (2007).

that reported by Heijen (2007). They assume that consumers correctly observe the environmental harm rendered by different products. Instead of informing consumers, the environmental group undertakes a costly advertising campaign that increases the consumers' distaste for environmental harm. Regardless of whether a firm can affect its level of environmental harm, the presence of an environmental group reduces the aggregate level of environmental harm. The current paper assumes that consumers' preferences cannot be altered, but consumers cannot perfectly observe the environmental harm rendered by the products they consume. An incumbent firm misreports its harm through false advertising. The analysis presented in this paper stands in stark contrast from Heijen and Schoonbeek (2008), in that all advertising is conducted by the firm. There is no market regulator or environmental group.

Van der Made and Schoonbeek (2009) examine the effect of consumers' preferences for green products on entry by green firms. Similar to the analysis in Heijen and Schoonbeek (2008), van der Made and Schoonbeek (2009) consider consumers that correctly observe the amount of environmental harm caused by the goods they consume, but whose preferences may be affected by an environmental group's advertising campaign. Here, consumers' information - not their preferences - determine the potential for profitable entry by a green firm and the overall market structure.

A second string of relevant literature examines the interaction between false advertising and market outcomes. The ability of advertising to increase demand has long been acknowledged by economists.[3] In some instances, this may enhance market efficiency. For example, advertising can reduce search costs and solve other information imperfections, resulting in more efficient markets. However, it is also plausible that advertising misinforms consumers or distorts their preferences, potentially reducing efficiency. In the context of advertising for polluting products, misinformation and

[3] See, for example, Dixit and Norman (1978), Salop (1979), and Schmalensee (1982).

distorted preferences have become an important focus of study. A number of recent studies have examined the welfare effects of false advertising, paying particular attention to markets for polluting products. Glaeser and Ujhelyi (2010) consider false advertising in a Cournot oligopoly setting and derive the welfare effects for the unregulated and regulated equilibria. They demonstrate that false advertising may be welfare enhancing when undertaken by a monopoly that cannot change its post-advertising price. In this limited setting, false advertising may enhance welfare by offsetting the deadweight loss associated with monopoly pricing. Relatedly, they demonstrate that misinformation always reduces consumer surplus. The present paper does not consider government policies aimed a curbing false advertising, but it does consider the welfare effect of false advertising, in a (vertically) differentiated products setting.

Hattori and Higashida (2011) and Hattori and Higashida (2012) consider the effects of false advertising in differentiated products markets. Hattori and Higashida (2011) examines the effects of false advertising in a market characterized by horizontally differentiated products. In this setting, they highlight the important role that an advertising externality plays in determining the effect of false advertising on welfare. When the advertising spillovers are large, and goods are more homogenous, less advertising occurs and consumers' switch decisions are less harmful to welfare. However, Hattori and Higashida (2011) do not identify cases in which false advertising in a horizontally differentiated products market may enhance consumer surplus or welfare. Hattori and Higashida (2012) conduct a similar analysis in the context of a vertically differentiated product market. They demonstrate that the dominant effect of false advertising on consumer surplus arises from price competition. The authors demonstrate that false advertising by the "low quality" firm may increase consumer surplus, through more vigorous price competition. Conversely, false advertising by the "high quality form" always reduces welfare, as it softens price competition. A similar welfare result is obtained in the following sections of the current paper.

This section identifies the recent treatment of environmental harm as a factor introducing vertical product differentiation. It identifies a recent literature related to the effects of informative advertising (by environmental groups) in polluting industries. Informative advertising that affects consumers' distaste for pollution may incentivize pollution abatement and facilitate entry by green firms. This paper differs from previous studies of green advertising. The current paper assumes that consumers' preferences are immutable, and that green advertising does not inform consumers of actual quality. The current paper only considers greenwash. This section also identifies an accepted role of false advertising as a strategic instrument, available to polluting firms when the consumers they serve internalize environmental harm. It presents a number of results related to the welfare effects of false advertising and demonstrates that the welfare effects are market-specific. That is, false advertising has ambiguous effects on consumer surplus and welfare, that cannot be resolved without detailed information on market structure and conduct. The current paper considers market entry, and thus deals with changing market structures. As the structure of the market changes, the welfare and environmental implications of greenwash are not straightforward. This paper combines both of these strings of literature, as it considers strategic false advertising in a vertically differentiated market for a polluting product.

The current paper makes a number of important contributions to the extant literature. It is the first paper, to my knowledge, that considers greenwash advertising as an instrument capable of altering market structure. Previous studies that analyze greenwash advertising have considered managerial incentives or consumer beliefs in the presence of greenwash (See, for example, Lyon and Maxwell (2011) and Mason (2013)); none has considered market-level effects. Additionally, the results presented in this paper are surprising and informative, as they provide an argument in favor of some positive level of greenwash. The paper demonstrates that false advertising can enhance consumer welfare and reduce pollution.

Section 3 of this paper analyzes the competitive effects of green advertising by an incumbent monopolist in a vertically oriented market, where products are differentiated by the amount of environmental harm resulting from their production. The analysis demonstrates the ability of an incumbent monopolist to strategically employ green advertising to prevent entry by a greener entrant. Moreover, it examines the effect of this strategic behavior on market structure. As identified in the extant literature, the effects of false advertising on welfare and environmental harm substantively change as the market structure is altered. Section 4 presents a welfare analysis and the implications for aggregate environmental harm. Section 5 provides brief concluding remarks and discusses some areas for future research.

1.3 Theoretical Model: Vertical Differentiation

This paper employs a game theoretic model of vertically differentiated products. Products differ in the exogenously assigned level of environmental harm that their production creates, but are otherwise identical. This model is applied to a market served by an incumbent monopolist and a greener potential entrant. Before the green firm makes its entry decision, the brown incumbent may undertake a costly greenwashing campaign, making its product appear more green than it actually is. The analysis presented in this section pays particular attention to strategic entry deterring behavior by the incumbent monopolist and its effect on consumer welfare and aggregate environmental harm.

The model assumes that a continuum of otherwise-homogenous consumers differ in their (dis)taste for environmental harm. Each consumer internalizes a portion of the environmental harm rendered by the product they consume. Based on their marginal valuations of the pollution attribute, consumers decide whether to purchase one unit of the available variants, or to abstain from purchasing the polluting product altogether. Some consumers' (dis)tastes for pollution are sufficiently high to ensure that they do not consume the product. No "full coverage" assumption is made; the producer of the

highest quality available variant can affect the total number of consumers that choose to purchase the product – or the total quantity transacted. [4]

This paper considers two possible variants of the polluting product. The variants differ in the (exogenously assigned) level of pollution that each creates; the green(er) variant is assumed to be less harmful than the incumbent monopolist's variant. Consumers perfectly observe the amount of harm created by the non-advertised green product, but their perception of the brown variant's harm may be altered by environment-related advertising, or greenwashing. A consumer with (dis)taste parameter θ derives the following utility from purchasing one unit of the *i*th variant of the differentiated product:

$$U(\theta) = V - \theta e_i - p_i, \tag{1–1}$$

where $V > 0$ is the gross valuation of the product. e_i and p_i are the environmental harm and market price associated with consuming one unit of the *i*th firm's variant, respectively. The utility derived from not purchasing either variant of the product is normalized to zero. It is assumed for simplicity that tastes for environmental harm, θ, are uniformly distributed on the interval $[0, 1]$. Consumers purchase one unit of the variant that offers the highest level of utility. Absent advertising, some individuals have very strong preferences for green products and choose to abstain from consuming the polluting product. Of the individuals that do purchase one of the two available variants, consumers that have a stronger preference for green products (i.e., a higher value of θ) pay a higher price for the green variant, while consumers with a weaker preference for environmental cleanliness purchase the brown variant at a lower price. Fully-informed consumers make efficient consumption choices by internalizing environmental harm.

[4] Full coverage may be achieved with an extremely strong level of greenwash.

Consumers may not correctly observe the environmental harm differences of the products they consume, as acknowledged by a number of analyses of differentiated products.[5] Instead, they may rely on information provided to them by the polluting firms and/or third-party agents (e.g., environmental advocacy groups). Here, it is assumed that consumers' only source of information is the firm producing the variant. The brown firm may mislead consumers by undertaking a costly greenwashing campaign and reducing the level of perceived environmental harm. The brown firm incurs a positive advertising cost if it wishes to advertise its product as being more green than it actually is. Such deceitful behavior serves to distort the market demand in favor of the brown firm.[6] This paper does not consider greenwashing by the green firm, as the timing structure of the game allows for precommittment by the incumbent.

Firms do not incur any marginal production costs.[7] Rather, they incur a fixed entry fee, F, which the incumbent is assumed to have paid before the start of the game. When the incumbent engages in greenwashing, the cost of falsely reporting a reduced level of environmental harm, $\hat{e_B}$, to consumers is given as $c(e_B - \hat{e_B}) = \frac{k(e_B - \hat{e_B})^2}{2}$, where e_B is the actual environmental harm associated with the incumbent's variant. The parameter k measures the how costly it is to mislead consumers.[8] Importantly, the actual levels

[5] For example, see Heijen and Schoonbeek (2008), van der Made and Schoonbeek (2009), Glaerser and Ujhelyi (2010), Hattori and Higashida (2011a), and Hattori and Higashida (2011b).

[6] This paper does not consider green advertising that serves to inform consumers of actual product differences. Instead, it assumes that firms can costlessly reveal their actual environmental harm.

[7] Including marginal production costs is quite simple, but they do not enhance the analysis presented in the present paper.

[8] As noted by Hattori and Higashida (2011) and Hattori and Higashida (2012), the cost of false advertising captures the gullibility of consumers. That is, the cost of misleading consumers is determined by their naivety.

of environmental harm are exogenously assigned and do not change (i.e., e_B and e_G are fixed.). The cost of misrepresenting environmental harm is increasing in the level of misrepresentation at an increasing rate. This convex cost structure ensures that the incumbent has a unique, nonzero profit-maximizing reported level of harm. Additionally, it does not prevent the incumbent from attempting to convey its variant as more green than the entrant's variant.

This section proceeds with an analysis of the three-stage game described above. The incumbent firm undertakes some (positive) amount of greenwash advertising, the green entrant chooses whether to enter, and the extant firms set prices. The issue of primary concern is whether the incumbent undertakes a level of greenwash that alters the market structure, and how such behavior affects consumer welfare and aggregate environmental harm. In order to identify candidate Subgame Perfect Nash Equilibria, this section is organized according to backward induction, beginning with the price setting and entry stages.

1.3.1 Stages 2 and 3: Price Setting and the Effect on Green Entry

A brown incumbent firm greenwashes its product without the possibility of being exposed by the environmental group. It falsely advertises its product by reporting a level of environmental harm that is less than the actual level. In the absence of a government regulator or an environmental group, consumers accept the firm's report of its environmental harm and make their purchase choices accordingly. The final stage of the game is characterized by price competition, in which each firm sets a price for its variant. In order to fully characterize all possible Subgame Perfect Nash Equilibria, we must consider four market arrangements that could arise in the final stage of the game: 1) The brown variant is reported as being less environmentally friendly than the green variant, and the green firm enters; 2) The brown variant is reported as being less environmentally friendly than the green variant, and the green firm does not enter; 3) The brown variant is reported as being more environmentally friendly than the green

variant, and the green firm does not enter; and 4) The brown variant is reported as being more environmentally friendly than the green variant, and the green firm enters. The determination of which of the four possible equilibria arises is dependent upon the fixed entry cost and the marginal cost of misreporting the incumbent's level of environmental harm.

Case 1: The brown variant is reported as being less environmentally friendly than the green variant, and the green firm enters: If the green entrant finds it profitable to enter (i.e., it can cover its fixed cost F with the profits earned in the final stage), the two firms share the market. Following from Equation 1–1, consumers purchase one unit of the variant that yields the highest utility, or they purchase neither. Consumers that have a strong distaste for environmental harm choose to purchase from the green entrant at a higher price, while consumers with less distaste for environmental harm choose to purchase from the brown incumbent at a lower price. It is assumed that the market is not fully covered; that is, some consumers (with a particularly strong distaste for environmental harm) choose not to purchase either variant of the polluting product. When the green firm chooses to enter, and consumers correctly perceive its variant as the greener one, the respective demand functions faced by the green and brown firm are given as:

$$q_G(p_B, p_G, \hat{e_B}, e_G) = \frac{V - p_G}{(e_G)} - \frac{p_G - p_B}{(\hat{e_B} - e_G)}, \textit{and} \tag{1–2}$$

$$q_B(p_B, p_G, \hat{e_B}, e_G) = \frac{p_G - p_B}{(\hat{e_B} - e_G)}, \tag{1–3}$$

where p_B and p_G are the prices of the brown and green variants respectively. The variable $\hat{e_B}$ represents the level of environmental harm that the incumbent reports to consumers, and e_G represents the exogenously assigned amount of environmental harm caused by the entrant's variant. That is, $\hat{e_B}$ is the incumbent firm's false report of environmental harm, which is assumed to always be less than e_B. These demand functions characterize the consumers' responses to the final stage equilibrium prices.

In Stage 3, the two firms simultaneously set prices for their respective variants. Without loss of generality, it is assumed that the firms do not incur marginal costs of production. Profit maximization is synonymous with revenue maximization. Specifically, if the fixed costs of entry are small enough to facilitate entry, the entrant and incumbent solve the following maximization problems, respectively.

$$\max_{p_G} \quad \pi_G = \left[\frac{V - p_G}{(e_G)} - \frac{p_G - p_B}{(\hat{e_B} - e_G)}\right] p_G, \textit{and} \tag{1–4}$$

$$\max_{p_B} \quad \pi_B = \left[\frac{p_G - p_B}{(\hat{e_B} - e_G)}\right] p_B. \tag{1–5}$$

The First Order Conditions for profit maximization in Case 1 show that the brown incumbent sells to consumers with less distaste for environmental harm. Specifically, it sells to consumers characterized by $\theta \in [0, \frac{V}{4\hat{e_B} - e_G}]$ and receives a price of $p_B = \frac{V(\hat{e_B} - e_G)}{4\hat{e_B} - e_G}$. The green entrant sells to customers with stronger distastes for environmental harm, those characterized by $\theta \in [\frac{V}{4\hat{e_B} - e_G}, \frac{V(2\hat{e_B} + e_G)}{e_G(4\hat{e_B} - e_G)}]$. The green entrant charges a price of $p_G = \frac{2V(\hat{e_B} - e_G)}{4\hat{e_B} - e_G}$. The price of the green variant is twice that of the brown variant (i.e., $p_B = \frac{p_G}{2}$). This case arises when the fixed cost of entry are sufficiently low.

Determining whether the green entrant chooses to enter in Stage 2 requires a comparison of its expected payoffs to entry (i.e., post-entry revenue) and its fixed cost of entry. It enters provided that the fixed cost of entry is sufficiently low. More specifically, the green entrant chooses to enter if:

$$F \leq \frac{4V^2(\hat{e_B} - e_G)\hat{e_B}}{(4\hat{e_B} - e_G)^2 e_G}. \tag{1–6}$$

The maximum fixed entry cost that results in entry by the green firm is increasing in the level of environmental harm caused by the brown incumbent. It is more likely that the entrant can cover its fixed costs when consumers believe that the incumbent's variant is dirtier. Conversely, if the brown firm reduces the perceived harm of its product through greenwash, the entrant finds it more difficult to enter. Any greenwash by the incumbent serves to make entry less likely.

Interestingly, the green firm's revenues fall to zero when the incumbent reports its variant as being equally as harmful as the entrant's variant, implying that at some $\hat{e_B} > e_G$, the green firm is unable to recover its fixed costs of entry. This feature of the model stands in contrast to Schmalensee (1982) and Hattori and Higashida (2011a), where false advertising creates a positive externality for competitors. No such externality exists in this model. Here, false advertising always reduces the entrant's post-entry revenues through heightened price competition.

Case 2: The brown variant is reported as being less environmentally friendly than the green variant, and the green firm does not enter: If the fixed cost of entry, F, is sufficiently large, or if the entrant's expected post-entry market share and profitability are sufficiently reduced, the green firm is foreclosed from the market. Specifically, if the condition in Equation 1–6 does not hold, the green firm does not enter. The brown incumbent produces the only available product variant and serves all consumers characterized by $\theta \in [0, \frac{V-p_B}{\hat{e_B}}]$. The incumbent sets its monopoly price to maximize its profits:

$$\max_{p_B} \quad \pi_B = \left[\frac{V - p_B}{\hat{e_B}}\right] p_B. \tag{1–7}$$

The incumbent sells its variant to all consumers characterized by $\theta \in [0, \frac{V}{2\hat{e_B}}]$ at a price, $p_B = \frac{V}{2}$. The brown incumbent earns $\pi_B = \frac{V^2}{4\hat{e_B}}$. Comparing these profits to those earned by the incumbent in Case 1, it is easily seen that the brown incumbent experiences higher profits when it does not face a competitor in the final stages of the game, making monopoly status particularly desirable. As identified in Equation 1–6, this outcome is dependent upon the incumbent undertaking a sufficiently high level of greenwash.

Case 3: The brown variant is reported as being more environmentally friendly than the green variant, and the green firm does not enter: It is possible that the incumbent chooses to report its variant as less harmful that the entrant's greener variant (i.e., $\hat{e_B} < e_G$). As highlighted in Case 1, when the brown incumbent's level of reported harm is close to the green potential entrant's level, the green firm is not be able to enter

profitably in Stage 2. Consequently, when $\hat{e_B}$ falls below e_G, the green firm remains out of the market, similar to Case 2. Only once $\hat{e_B}$ falls sufficiently below e_G can the green firm enter – with the "low quality" variant. When the brown firm reports its variant as slightly less harmful than the green entrant's variant, the incumbent firm remains a monopolist, as it was in Case 2. It continues to charge a price of $p_B = \frac{V}{2}$ and serve consumers characterized by $\theta \in [0, \frac{V}{2\hat{e_B}}]$. As this case occurs when $\hat{e_B}$ takes a lower value than in the previous case, more consumers decide to purchase the monopolist's variant.

Case 4: The brown variant is reported as being more environmentally friendly than the green variant, and the green firm enters: As noted above, the brown incumbent can report its variant as more environmentally friendly than the green firm's variant. When the brown variant is perceived as only slightly more friendly than the green variant, the green firm is not able to enter in Stage 2, as its post-entry profits will not cover the fixed cost of entry. Once the brown variant is reported as substantially more friendly than the green variant, the green firm may be able to recover its fixed entry cost by entering with the "low quality" variant. In this case, the brown variant is viewed by consumers as the "high quality" variant, but the green firm still enters.

Case 4 differs somewhat from the other cases, as it includes the market configuration in which all potential consumers choose to purchase at least one of the two variants. In all of the other cases, there was some group of consumers that chose not to purchase either variant of the polluting product. In Case 4, the brown incumbent may choose to report a level of environmental harm sufficiently low that it induces all potential consumers to purchase. This outcome is referred to as "full coverage." It is, however, also possible that the reported level of harm is not sufficiently low to achieve full coverage. Here, we must consider two subcases: Subcase 4a: No Full Coverage and Subcase 4b: Full Coverage.

Subcase 4a: No Full Coverage: Unlike the previous cases, in this case, $\hat{e_B} < e_G$, implying that consumers that have a stronger distaste for environmental harm choose to purchase from the brown incumbent at a higher price, while consumers with less distaste for environmental harm choose to purchase from the green entrant at a lower price. In this subcase, we assume that there are some consumers whose distaste for environmental harm is sufficiently strong that they abstain from purchasing either variant. When the brown firm falsely reports its product as the greener product, and when full coverage is not achieved, the respective demand functions faced by the green and brown firm are given as:

$$q_G(p_B, p_G, \hat{e_B}, e_G) = \frac{p_B - p_G}{(e_G - \hat{e_B})}, \textit{and} \tag{1–8}$$

$$q_B(p_B, p_G, \hat{e_B}, e_G) = \frac{V - p_B}{\hat{e_B}} - \frac{p_B - p_G}{(e_G - \hat{e_B})}, \tag{1–9}$$

These demand functions characterize the consumers' responses to the final stage equilibrium prices when both firms are present, but consumers incorrectly rank them, in terms of the environmental harm each creates.

The two firms simultaneously set prices for their respective variants. Specifically, if the fixed costs of entry are small enough to facilitate entry, the entrant and incumbent solve the following maximization problems, respectively.

$$\max_{p_G} \quad \pi_G = \left[\frac{p_B - p_G}{(e_G - \hat{e_B})}\right] p_G. \tag{1–10}$$

$$\max_{p_B} \quad \pi_B = \left[\frac{V - p_B}{(\hat{e_B})} - \frac{p_B - p_G}{(e_G - \hat{e_B})}\right] p_B, \textit{and} \tag{1–11}$$

The First Order Conditions for profit maximization in Case 3 show that the brown incumbent sells to consumers with more distaste for environmental harm. Specifically, it sells to consumers characterized by $\theta \in [\frac{V}{4e_G - \hat{e_B}}, \frac{V(2e_G + \hat{e_B})}{\hat{e_B}(4e_G - \hat{e_B})}]$and receives a price of $p_B = \frac{2V(e_G - \hat{e_B})}{4e_G - \hat{e_B}}$. The green entrant sells to customers with stronger distastes for environmental harm, those characterized by $\theta \in [0, \frac{V}{4e_G - \hat{e_B}}]$. The green entrant charges

a price of $p_G = \frac{V(e_G - \hat{e_B})}{4e_G - \hat{e_B}}$. The price of the brown variant is twice that of the green variant (i.e., $p_G = \frac{p_B}{2}$). Determining whether the green entrant chooses to enter in Stage 2, when $\hat{e_B} < e_G$ requires a comparison of its expected payoffs to entry (i.e., post-entry revenue) and its fixed cost of entry. It enters provided that the fixed cost of entry is sufficiently low. More specifically, the green entrant chooses to enter if:

$$F \leq \frac{V^2(e_G - \hat{e_B})}{(4e_G - \hat{e_B})^2}. \tag{1–12}$$

The maximum fixed entry cost that results in entry by the green firm is decreasing in the reported level of environmental harm caused by the brown incumbent. It is more likely that the entrant can cover its fixed costs when consumers believe that the incumbent's variant is cleaner, once the incumbent has falsely reported its variant as more environmentally friendly than the green entrant's. Conversely, if the brown firm slightly increases the perceived harm of its product through greenwash (as to not move it to another one of the market arrangement cases), the entrant finds it more difficult to enter. Any greenwash by the incumbent serves to make entry more likely. This results arises from heightened price competition when the two variants are perceived as less differentiated by consumers. When $\hat{e_B}$ is sufficiently low to satisfy Equation 1–12, the market arrangement shifts from that described in Case 3 to that described by Subcase 4a.

Subcase 4b: Full Coverage: If false advertising is extremely strong and effective, the market eventually becomes fully covered. That is, all potential consumers choose to purchase one of the two available product variants; no one abstains from the market. This market structure is distinguished from the previous case by altering the incumbent's demand considerations. The incumbent no longer considers the possibility of drawing new consumers into the market. Demand for its variant becomes:

$$q_B(p_B, p_G, \hat{e_B}, e_G) = 1 - \frac{p_B - p_G}{e_G - \hat{e_B}}, \tag{1–13}$$

Similar to the analysis presented for Case 3, the two firms simultaneously set prices for their respective variants, and the incumbent's product is incorrectly believed to be the "high quality" variant. The entrant and incumbent solve the following maximization problems, respectively:

$$\max_{p_G} \quad \pi_G = \left[\frac{p_B - p_G}{e_G - \hat{e_B}}\right] p_G. \tag{1–14}$$

$$\max_{p_B} \quad \pi_B = \left[1 - \frac{p_B - p_G}{e_G - \hat{e_B}}\right] p_B, \textit{and} \tag{1–15}$$

The First Order Conditions for profit maximization in Case 3 show that the brown incumbent sells to consumers with more distaste for environmental harm. Specifically, it sells to consumers characterized by $\theta \in [\frac{1}{3}, 1]$and receives a price of $p_B = \frac{2(e_G - \hat{e_B})}{3}$. The green entrant sells to customers with weaker distastes for environmental harm, those characterized by $\theta \in [0, \frac{1}{3}]$. The green entrant charges a price of $p_G = \frac{(e_G - \hat{e_B})}{3}$.

The incumbent selects a level of greenwash for its product, and the intensity of this false advertising determines the equilibrium market arrangement. Four possible cases were explored above: Case 1) The brown variant is reported as being less environmentally friendly than the green variant, and the green firm enters; Case 2) The brown variant is reported as being less environmentally friendly than the green variant, and the green firm does not enter; Case 3) The brown variant is reported as being more environmentally friendly than the green variant, and the green firm does not enter; and Case 4) The brown variant is reported as being more environmentally friendly than the green variant, the green firm does enters. Case 4 is separated into two subcases, one in which full coverage is not achieved and one in which it is. Depending upon the green firm's cost of entry and the incumbent's marginal cost of misrepresenting its product, one of these four market structures arises in the game's Subgame Perfect Nash Equilibrium. If the fixed cost of entry is low, and greenwashing is low, Case 1 arises, and the incumbent charges a lower price than the entrant and sells to consumers with less (dis)taste for environmental harm. As the fixed costs of entry increases, and/or the

amount of greenwashing increases, Case 2 or Case 3 arises in equilibrium, and the incumbent firm serves as a monopolist. If the fixed costs of entry are sufficiently low, and greenwashing is sufficiently pervasive, Case 4 arises in equilibrium, and the green firm will enter as the "low quality" firm. The entry choice is determined by Conditions 1–6 and 1–12, while the amount of optimal greenwash is determined by the marginal cost of greenwash.

1.3.2 Stage 1: Greenwashing

In Stage 1, the brown incumbent chooses the level of greenwash to apply to its variant. It reports to consumers that its product is less harmful than it actually is, deceitfully increasing the demand for its variant.[9] In this model, consumers believe that the incumbent's variant is cleaner than it actually is and make their purchase decisions according to that false belief. The model assumes that once greenwash has been undertaken by the incumbent firm, neither the entrant nor consumers are able to identify the actual amount of harm caused by the incumbent. This assumption is based on the notion that such information would often be unrecoverable in reality. Simply looking at or consuming a product does not reveal the amount of harm caused by its production. When a consumer purchases an organic apple in the supermarket, for example, they are not able to verify that the apple was, in fact, organically produced. Rather, they rely on the provision of information by the producer and are made to believe the producer's claim. Many polluting products share this characteristic; they are, in essence, credence goods.

As was done in Subsection 3.1, four unique market arrangements, across which the market structure substantively differs, that could arise in the final stage of the

[9] I assume that the exogenously assigned levels of actual environmental harm are sufficiently differentiated that the incumbent does wish to undertake some level of greenwash. I provide the necessary parameter restriction below.

game must be considered. The determination of which of these four market structures arises is dependent upon the fixed entry cost and the marginal cost of misreporting the incumbent's level of environmental harm. This subsection characterizes the Subgame Perfect Nash Equilibrium candidates in each market structure, by focusing on the incumbent's first stage choice of greenwashing. Particular attention is paid to how the incumbent responds to the presence of discontinuities in its profit function that arise from altering the market structure.

Case 1: The brown variant is reported as being less environmentally friendly than the green variant, and the green firm enters: If the brown incumbent correctly reports its variant as more harmful than the entrant's greener variant, and if the entrant finds it profitable to enter (i.e., its fixed cost F is sufficiently low to facilitate enetry), the two firms share the market. Moreover, the incumbent's variant is correctly view as the "low quality" variant by consumers. Solving the First Order Conditions for pricing obtained in Equation 1–10 and Equation 1–11, the Stage 1 profit maximization problem in Case 1 is described by:

$$\max_{\hat{e_B}} \quad \pi_B = \frac{V^2(\hat{e_B} - e_G)}{(4\hat{e_B} - e_G)^2} - \frac{k(e_B - \hat{e_B})^2}{2}. \tag{1–16}$$

The profit maximizing report when the entrant enters and the incumbent does not report its variant as less harmful than the entrant's variant, $\hat{e_B}$, must satisfy:

$$\frac{V^2(4\hat{e_B} - 7e_G)}{(4\hat{e_B} - e_G)^3} = k(e_B - \hat{e_B}). \tag{1–17}$$

Here, the analysis is restricted to cases in which $e_B \geq \frac{7e_G}{4}$, as violating such a restriction would imply that the brown firm does not wish to greenwash its product.[10] It is apparent that within this case, reducing the marginal cost of misleading consumers

[10] Violating this restriction would imply that the brown incumbent could profitably report its variant as more harmful than it actually is. This feature arises, because products that are less differentiated result in more intense price competition in the final stage.

results in more greenwash. Without any shift in market structure, reducing the cost of greenwash results in more greenwash.

Additionally, any reduction in the cost of greenwash results in more environmental harm. The level of environmental harm caused by each product is obtained from the product of that product's (actual) per unit harm and the quantity produced of that product. Defining the aggregate level of environmental harm as $\sum Q_i e_i$, over all active firms, the level of aggregate environmental harm that arises in Case 1 is given as:

$$H = \frac{V(2\hat{e_B} + e_B)}{4\hat{e_B} - e_G}. \tag{1–18}$$

It is easy to see that the aggregate level of environmental harm is decreasing as $\hat{e_B}$ increases, or environmental harm increases as the incumbent greenwashes its product. Until the incumbent greenwashes its product enough to foreclose entry, aggregate environmental harm is unambiguously increasing as the reported level of harm falls. Moreover, the rate at which aggregate harm increases in the amount of greenwash is increasing.

Consumer welfare provides an additional dimension on which to consider the effect of false advertising. Within this case, greenwashing serves to intensify price competition, which benefits consumers. Defining consumer surplus as $CS \equiv \int_0^{\hat{\theta}} V - \theta e_B - p_B \, d\theta + \int_{\hat{\theta}}^{\tilde{\theta}} V - \theta e_G - p_G \, d\theta$, where consumers characterized by $\theta \in [0, \hat{\theta}]$ purchase the variant offered by the brown incumbent and consumers characterized by $\theta \in [\hat{\theta}, \tilde{\theta}]$ purchase the variant offered by the green entrant, analyzing the effect of greenwash on consumer welfare is straightforward. Reductions in the incumbent's reported level of environmental harm below its actual level of harm initially increase consumer surplus. Consumer's benefit from false advertising, whenever $\hat{e_B} > \frac{4e_B - 3e_G}{16}$; however, once the reported level of harm falls below this threshold, greenwash begins to harm consumers. It is not clear whether greenwash is ever able to harm consumer surplus within Case 1, because high fixed costs of entry may imply that the condition above is only violated when the

incumbent's level of greenwash forecloses the market. As a consequence, Consumer surplus produces two candidate maxima for consumer surplus.

Corollary 1. *When $\hat{e_B} > e_G$, and the entrant is able to profitably enter:*

(i) Any increase in the marginal cost of greenwash reduces the amount of greenwash undertaken by the incumbent at a decreasing rate.

(ii) Any increase in the reported level of environmental harm by the incumbent decreases aggregate environmental harm at a decreasing rate.

(iii) the reported level of harm by the incumbent that maximizes consumer surplus is less than e_B. When $\hat{e_B} = \frac{4e_B - 3e_G}{16}$ results in entry by the green firm, $\hat{e_B} = \frac{4e_B - 3e_G}{16}$ maximizes consumer surplus. When $\hat{e_B} = \frac{4e_B - 3e_G}{16}$ does not result in entry by the green firm, a reported level of harm just above the entry threshold level of harm maximizes consumer surplus.

Reducing the marginal cost of misleading consumers also makes it more likely that the incumbent will foreclose the entrant from the market, as the entrant's potential revenues fall as the incumbent greenwashes its variant. Defining $\tilde{F}(\hat{e_B}) \equiv \frac{4V^2(\hat{e_B} - e_G)\hat{e_B}}{(4\hat{e_B} - e_G)^2 e_G}$ as the threshold level of entry cost, any fixed entry cost $F > \tilde{F}(\hat{e_B})$ is prohibitively high for the entrant to recover post-entry. Greenwashing by the brown incumbent reduces the likelihood of entry by the green entrant, because it reduces the entry cost threshold. $\tilde{F}(\hat{e_B})$ is increasing in $\hat{e_B}$, or decreasing in the amount of greenwash, $e_B - \hat{e_B}$. That is, when the brown incumbent reports its product as less harmful to consumers, the threshold level of fixed costs for entry foreclosure falls, and it becomes more likely that the fixed entry cost is prohibitively high.

As the marginal cost of greenwashing decreases, the profit-maximizing level of greenwash increases. These heightened greenwash efforts by the incumbent make entry less likely. Once the amount of greenwash is sufficient to foreclose the market from entry by the green firm, the incumbent's profits exhibit an upward jump. That is, not surprisingly, the incumbent's profits experience an upward jump when its greenwash

efforts secure monopoly status. Additionally, as the marginal benefit of greenwash also jumps up when entry is prevented, there is an upward jump in the profit-maximizing amount of greenwash when the market arrangement moves from that described by Case 1 to that described by Case 2.

Case 2: The brown variant is reported as being less environmentally friendly than the green variant, and the green firm does not enter: If the fixed cost of entry, F, is sufficiently large, the green entrant is foreclosed from the market. Specifically, if the condition in Equation 1–6 does not hold, the green firm cannot profitably enter. The brown incumbent produces the only product variant and serves all consumers characterized by $\theta \in [0, \frac{V}{2\hat{e_B}}]$. The incumbent sets its monopoly price to maximize its profits:

$$\max_{\hat{e_B}} \quad \pi_B = \left[\frac{V^2}{4\hat{e_B}}\right] - \frac{k(e_B - \hat{e_B})^2}{2}. \tag{1–19}$$

The profit maximizing report when the entrant does not enter, and the incumbent does not report its variant as more harmful than the entrant's variant, $\hat{e_B}$, is given by the following First Order Condition:

$$\frac{V^2}{4\hat{e_B}^2} = k(e_B - \hat{e_B}). \tag{1–20}$$

It is easily shown that increases in the marginal cost of greenwashing increases the incumbent firm's profit-maximizing report — so long as those reductions actually lead to more greenwashing. In order to rule out ranges of k over when the profit maximizing report is held constant, we must carefully consider the incumbent's greenwashing behavior in the neighborhood of the report that deters entry (between Case 1 and Case 2). The incumbent's profits jump upward when its report deters entry. More importantly, the marginal benefit of greenwash also jumps up. When the incumbent's report is sufficiently low to deter entry, its profit maximizing report jumps down. As a downward jump in the reported level of harm does not violate the entry deterrence condition, the

profit maximizing level of reported harm is not strategically held constant over any range of k in the neighborhood of the entry threshold.

Corollary 2. *If $\hat{e_B} > e_G$, when greenwash is sufficiently strong to foreclose the market to a greener entrant, the incumbent's profits exhibit an upward jump, and the marginal benefit of greenwash exhibits an upward jump. Together, these features imply that the profit maximizing report jumps down.*

The amount of aggregate environmental harm caused by the monopolist incumbent's product variant is given as $H = \frac{Ve_B}{2\hat{e_B}}$. Increases in the incumbent's level of reported environmental harm reduce aggregate environmental harm as a decreasing rate. This implies that greenwash by an incumbent increases aggregate harm at an increasing rate. Additionally, any increase in the marginal cost of greenwash reduces the aggregate level of environmental harm at a decreasing rate.

Case 3: The brown variant is reported as being more environmentally friendly than the green variant, and the green firm does not enter: There is no restriction regarding the incumbent's ability to report that its variant is less harmful than the potential entrant's variant. The incumbent may report that $\hat{e_B}$ is less than e_G. If the incumbent reports its variant as only slightly less harmful than the potential entrant's variant, the market remains foreclosed, effectively maintaining the monopoly structure outlined above for Case 2. Only when the incumbent's variant is reported as substantially cleaner than the entrant's variant can the entrant recover the fixed costs of entry. This occurs, because increased product differentiation softens post-entry price competition, allowing then entrant to recover its fixed entry cost by selling the "low quality" variant. As the incumbent's greenwash efforts become sufficiently strong to alter the market structure and facilitate entry by the greener entrant, the incumbent's profits exhibit a downward jump, but the marginal benefit of greenwash jumps up. Again, as in Case 2, the incumbent does not have an incentive to strategically avoid Case 4 by maintaining a constant level of greenwash that is just above the level that would facilitate entry.

When the incumbent's level of reported harm is set sufficiently low to foreclose the market (between Case 1 and Case 2), the profit-maximizing report jumps downward. Similarly, when the incumbent's level of reported harm is set sufficiently low to facilitate entry into the market (between Case 3 and Case 4), the profit-maximizing report also jumps downward. There is no range of k within the monopoly market structure over which the profit maximizing level of greenwash is held constant, because the marginal benefit of greenwash is consistent with the entry thresholds. Within the monopoly market structure, any increase in k increases the incumbent's profit-maximizing report at a decreasing rate.

Whenever the incumbent firm is able to secure a monopoly, increasing its marginal cost of greenwash reduces its profit-maximizing level of greenwash at a decreasing rate. This has straightforward implications for aggregate environmental harm and consumer surplus. Over the range of k that support a monopoly market structure, aggregate environmental harm is given as $H = \frac{Ve_B}{2\hat{e_B}}$. Regardless of whether $\hat{e_B} > e_G$, aggregate environmental harm falls at a decreasing rate as k increases. Consumer surplus jumps down whenever the market is foreclosed. Additionally, within the monopoly market structure, any increase in the marginal cost of greenwash results in increases consumer welfare. Here, consumer surplus is defined as $CS \equiv \int_0^{\hat{\theta}} V - \theta e_B - p_B \, d\theta$, where consumers characterized by $\theta \in [0, \hat{\theta}]$ purchase the variant offered by the brown incumbent. As the reported level of harm increases, within this monopoly market structure, consumers are made better off, unambiguously. Higher levels of reported harm reduce prices and inefficient product switching.

Corollary 3. *When greenwash by the incumbent prevents profitable entry by the green firm:*

(i) Any increase in the marginal cost of greenwash reduces the amount of greenwash undertaken by the incumbent at a decreasing rate.

(ii) Any increase in the marginal cost of greenwash reduce aggregate environmental harm at a decreasing rate.

(iii) Consumer surplus jumps down whenever entry is foreclosed, regardless of whether $\hat{e_B} > e_G$. Additionally, within the range of marginal costs of greenwash that gives rise to a monopoly market structure, increases in the marginal cost of greenwash increase consumer surplus at a decreasing rate.

Elevated monopoly profits by the incumbent give rise to discontinuities in the incumbent's profit function. The profit-maximizing reports in the neighborhoods of the entry thresholds, however, do not conflict with the entry cost conditions. As a consequence, the First Order Condition given in Equation 1–20 fully characterizes greenwashing behavior within the monopoly market structure. Additionally, within this market structure, any increase in the marginal cost of greenwashing reduces aggregate environmental harm at a decreasing rate and increases consumer surplus at a decreasing rate.

Case 4: The brown variant is reported as being more environmentally friendly than the green variant, and the green firm enters: It is possible that the incumbent chooses to report its variant as less harmful than the entrant's greener variant (i.e., $\hat{e_B} < e_G$), effectively jumping the greener entrant's quality designation and leading consumers to perceive its product as the "high quality" variant. When the brown variant is reported as only slightly less harmful than that of the green firm, positive entry costs prevent the green firm from entering, and the market remains a monopoly — as reported in Case 3. However, if the green firm's variant is viewed as sufficiently dirtier than the actual brown product, the green firm can profitably enter as the "low quality" competitor. The incumbent sells to consumers with a greater (dis)taste for environmental harm and charges a higher price than the greener entrant. Essentially, the two firms reverse roles (compared to Case 1). As was highlighted in the analysis of the price setting stage, Case 4 presents two unique subcases. In the first subcase, the incumbent's reported

level of harm is sufficiently high to avoid full market coverage. That is, some consumers choose not to purchase either variant, as even the incumbent's variant is perceived as too harmful by some consumers. In the second subcase, the incumbent's reported level of harm is sufficiently low to draw all consumers into the market, and full coverage is achieved.

Subcase 4a: No Full Coverage: When the brown incumbent jumps its rival (in terms of reported environmental harm), it is perceived as offering the "high quality" product. If the jump is sufficiently large, the green firm enters, resulting in a duopoly market structure. If that jump is not sufficiently large to draw all consumers into the market (i.e., to achieve full market coverage), the incumbent's Stage 1 maximization problem is given as follows:

$$\max_{\hat{e_B}} \quad \pi_B = \frac{4V^2(e_G - \hat{e_B})e_G}{(4e_G - \hat{e_B})^2\hat{e_B}} - \frac{k(e_B - \hat{e_B})^2}{2}. \tag{1–21}$$

When the reported level of harm is sufficiently low to facilitate entry, the incumbent's profits jump down, but the marginal benefit of greenwash jumps up. When entry (in Case 4) arises, the profit maximizing report jumps down. As in the other cases, increases in the marginal cost of greenwashing increase the profit-maximizing report of environmental harm by the incumbent at a decreasing rate. That is, $\frac{\partial \hat{e_B}}{\partial k} > 0$ and $\frac{\partial^2 \hat{e_B}}{\partial k^2} < 0$.

When the incumbent serves the market with the "high quality" variant, and the entrant serves the market with the "low quality" variant, a market that is not fully covered results in an amount of aggregate environmental harm:

$$H = \frac{Ve_G(2e_B + \hat{e_B})}{(4e_G - \hat{e_B})\hat{e_B}}. \tag{1–22}$$

It is easy to show that the aggregate level of environmental harm is decreasing as $\hat{e_B}$ increases, or environmental harm increases as the incumbent greenwashes its product. Additionally, as $\frac{\partial \hat{e_B}}{\partial k} > 0$, increasing the marginal cost of greenwashing leads to reductions (at a decreasing rate) in the aggregate level of environmental harm. Similar

to Case 1, within a market that is arranged as per Case 4 and is not fully covered, small increases in the marginal cost of greenwash always increase the incumbent's report at a decreasing rate and reduce harm at a decreasing rate.

When the incumbent misreports its variant as less harmful than the entrant's variant, greenwash always harms consumers. Unlike in Case 1 — where greenwash benefited consumers — greenwash in Case 4 serves to increase perceived product differentiation and soften price competition. Consumer also make inefficient purchase decisions, with consumers with the most sensitivity to environmental harm purchasing the more harmful variant.

Corollary 4. *When $\hat{e_B} < e_G$, and the entrant is able to profitably enter:*

(i) Any increase in the marginal cost of greenwash reduces the amount of greenwash undertaken by the incumbent at a decreasing rate.

(ii) Any increase in greenwash by the incumbent increases aggregate harm at an increasing rate.

(iii) Any increase in greenwash by the incumbent reduces consumer surplus.

When the incumbent offers what is perceived by consumers as the higher quality variant, and the market is not fully covered, small increases in k reduce greenwashing and aggregate environmental harm at a decreasing rate and enhance consumer welfare. To completely characterize the set of Subgame Perfect Nash Equilibria in which the incumbent offers the "high quality" variant, we must examine those equilibria that arise when the market is fully covered.

Subcase 4b: Full Coverage: For extremely strong levels of greenwash by the incumbent, the incumbent's product is perceived by consumers to be the "high quality" variant, and all consumers choose to purchase the product. That is, the market becomes fully covered. When the market is fully covered, the brown incumbent only greenwashes its variant to soften price competition. It does not need to consider the effect of its report or price on marginal consumers (for the market), as all consumers are

already purchasing one of the two available variants. In this case, the incumbent sells to the $\frac{2}{3}$ of the customers with the higher distastes for environmental harm and maximizes profits according to:

$$\max_{\hat{e_B}} \quad \pi_B = \frac{4(e_G - \hat{e_B})}{9} - \frac{k(e_B - \hat{e_B})^2}{2}. \tag{1–23}$$

The incumbent firm's profits jump upward, but the change marginal benefit of greenwashing is ambiguous when full coverage is achieved, relative to Subcase 4a. [11] Full coverage reduces the need for the incumbent firm to consider marginal consumers (for the market). This results in reduced downward price pressure, post-coverage, which leads profits to jump upward when full coverage is achieved. The effect of full coverage on the incumbent's profit-maximizing level of reported harm is less clear, because it is not clear whether the marginal benefit of greenwash is greater pre-coverage or post-coverage. The incumbent's profits unambiguously jump upward when the market becomes fully covered, but the effect of greenwash is less clear. Defining the pre-coverage marginal benefit of greenwash as MB_{NC} and the post-coverage marginal benefit of greenwash as MB_{FC}, we must consider both the possibility that $MB_{NC} > MB_{FC}$ and $MB_{NC} < MB_{FC}$ and characterize the effects of greenwashing behavior by the incumbent.

If $MB_{NC} > MB_{FC}$, for a range of values of k close to the coverage threshold, the profit-maximizing level of reported harm is held constant just below the coverage threshold level. If $MB_{NC} < MB_{FC}$, the reported level of harm jumps down at when full coverage is achieved, and there is no range of values of k close to the coverage threshold over which the profit-maximizing level of reported harm is held constant. Outside of the neighborhood of the coverage threshold, greenwash behavior is the same

[11] I define $\tilde{k}$ as the threshold level of marginal cost below which the market is fully covered.

for each of the two possibilities. Regardless of whether reported harm is increasing or held constant, the aggregate level of environmental harm is constant when the market is fully covered. Aggregate environmental harm is given as:

$$H = \frac{2e_B + e_G}{3} \tag{1–24}$$

Aggregate harm remains constant across all values of k that give rise to full market coverage. When the market is fully covered, the total market output and the market shares of the two firms remain constant. Consequentially, aggregate harm can neither be increased nor decreased. When the incumbent misreports its variant as less harmful than the entrant's variant, and the market is fully covered, greenwash decreases consumer surplus at a constant rate. When the market is fully covered, the market shares of each firm are constant; changes in the reported level of harm only affect the prices charged by each firm. When the incumbent firm reduces its reported level of harm, the variants are perceived as more differentiated, and prices rise. As a consequence, consumers are always harms by greenwash when the market is fully covered.

Corollary 5. *When $\hat{e_B} < e_G$, and when the market is fully covered, any increase in the marginal cost of greenwash that reduces the amount of greenwash undertaken by the firm increases consumer surplus at a decreasing rate.*

Results: Stage 1 Equilibrium Behavior: Behavior in the first stage of the game determines the structure of the market that the incumbent faces in the final price-setting stage of the game. Figure 1-1 depicts the relationship between the incumbent's profit maximizing level of reported environmental harm and the marginal cost of greenwashing.[12] It also highlights the four unique market structures and how the firm

[12] Figure 1-1 assumes that the marginal benefit of greenwash jumps down when the market becomes fully covered. In order to depict the case in which the marginal benefit

responds to those structural changes. Increases in the marginal cost of greenwashing are captured by increases in the parameter k. This parameter may represent the actual cost of a greenwashing campaign, or it may be interpreted as capturing the gullibility of consumers. It is less costly to deceive gullible consumers. The figure demonstrates that the amount of greenwash is generally decreasing at a decreasing rate as the marginal cost of greenwashing rises, with some apparent exceptions. There are two possible ranges of k over which the optimal level of greenwash is held constant — both arising when the market is fully covered. There are three possible discontinuous jumps at which increases in the marginal cost of greenwash result in less greenwashing, but there are no upward jumps in greenwash efforts. That is, increases in the marginal cost of greenwash may not always reduce greenwashing, but they never increase it. Moreover, when the market is not fully covered, any increase in the marginal cost of greenwash reduces greenwash efforts by the incumbent.

Lemma 1. *Increases in the marginal cost of greenwash may not always reduce greenwashing, but they never increase it. If the market is not fully covered, increasing the marginal cost of greenwash always reduces greenwashing efforts by the incumbent.*

For very low values of k, the market is fully covered, meaning that all consumers choose to purchase one unit of one of the two available variants. Full coverage is obtained when the incumbents reported level of environmental harm is sufficiently low to draw all consumers into the market.[13] The threshold report (for full coverage) by the incumbent is positive and arises at a positive marginal cost of greenwash. Within this range of very low marginal costs of greenwash that give rise to a fully covered

jumps up, the profit-maximizing report would jump down and not be held constant for a range of k in the neighborhood of the coverage threshold.

[13] When the market is fully covered, the entrant is able to enter, but consumers incorrectly view the incumbent's product as the "high quality" variant.

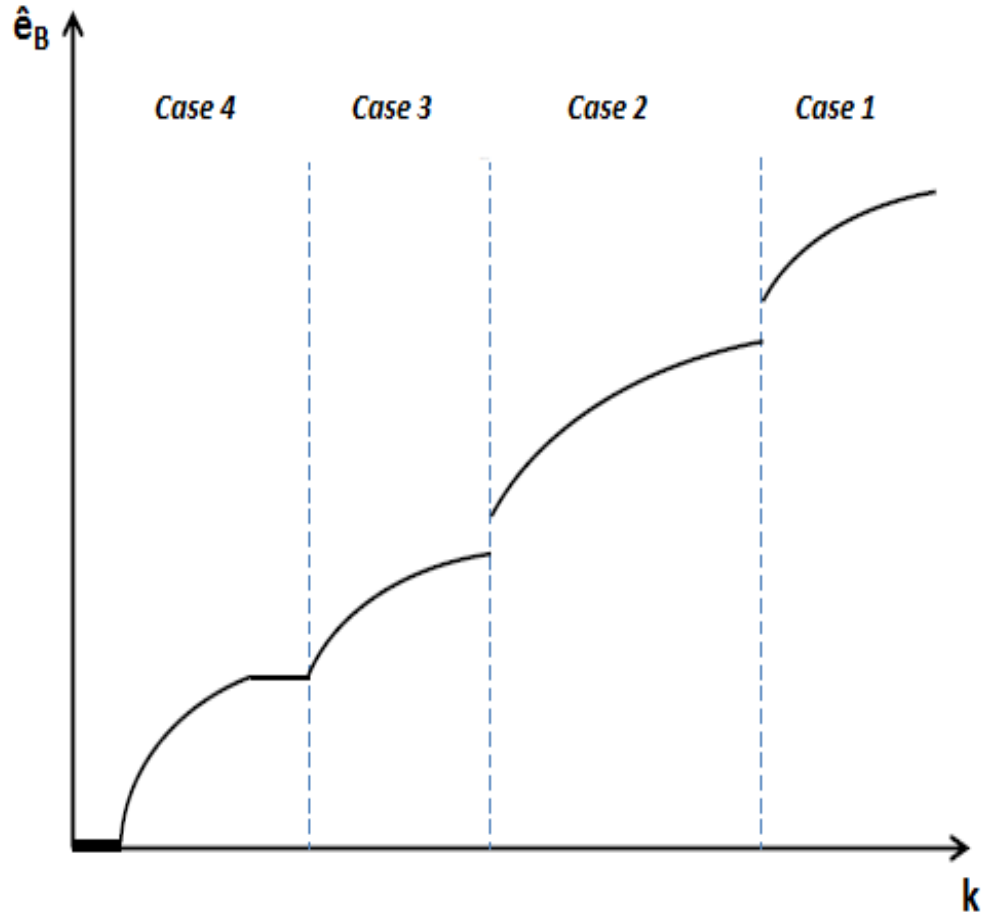

Figure 1-1. The Effect of *k* on Reported Harm

market, three possible relevant subranges can be identified. For extremely low values of *k*, the incumbent's report is held constant at zero. Within this subrange, the profit maximizing report is negative. In this model, the incumbent is not allowed to report its product as environmentally beneficial. Thus, for those extremely low values of *k*, the reported level of harm is equal to zero, implying that $\hat{e_B} = e_B$. Once *k* rises above the point at which the incumbent chooses to report a positive level of environmental harm, marginal increases in *k* reduce greenwashing at a decreasing rate. Eventually, in an effort to maintain a fully covered market, the incumbent may hold its greenwashing constant at the level that just covers the market. This final subrange only arises is the

marginal benefit of greenwash jumps up when the market is no longer fully covered; otherwise, this final subrange does not arise. As a consequence, within the fully covered market arrangement, there exist three possible subranges of k (listed in ascending order): a subrange over which the reported level of environmental harm is held constant at zero, a subrange over which marginal increases in k increase the reported level of environmental harm at a decreasing rate, and a subrange over which the reported level of environmental harm is held constant at a positive level. There are no discontinuous jumps in the reported level of environmental harm within the fully covered market structure.

As with lower values of k, when the market is fully covered, there is a range of marginal costs of greenwashing that give rise to a duopoly market in which consumers incorrectly perceive the incumbent's product as the "high quality" variant, but the market is not fully covered. That is, the reported level of environmental harm is sufficiently high to lead the most environmentally conscious consumers to abstain from purchasing either variant. Within the range of marginal costs of greenwash that gives rise to such a market structure, any increase in the marginal cost of greenwash reduces greenwashing by the incumbent at a decreasing rate.

For marginal costs of greenwash that result in the incumbent choosing a reported level of environmental harm close to the entrant's actual level of harm, the entrant cannot recover the fixed costs of entry, and the incumbent serves the market as a monopolist. This monopoly market structure can arise when $\hat{e_B} > e_G$ or $\hat{e_B} < e_G$, so long as the two are sufficiently close. When k rises sufficiently high to secure a monopoly for the incumbent (by moving from Case 4 to Case 3), the incumbent's reported level of harm jumps up. Within the monopoly structure, any increase in the marginal cost of greenwash reduces greenwash at a decreasing rate. Finally, once k rises high enough to facilitate entry (between Case 2 and Case 1), the incumbent's reported level of harm jumps up again.

For higher marginal costs of greenwashing, greenwash by the incumbent is too weak to deter entry by the greener firm, and a duopoly market in which consumers correctly view the incumbent's product as the "low quality" variant arises. Within this market structure, any increase in the marginal cost of greenwash reduces greenwashing by the incumbent at a decreasing rate.

A brown incumbent monopolist can greenwash its product to increase its own market share in the vertically differentiated market. By falsely portraying its product as less environmentally harmful than it actually is, the incumbent attracts consumers with higher distastes for environmental harm than would normally buy its product variant. Given the vertical nature of green products and positive entry costs, greenwash by an incumbent has the ability to alter the market structure. This section demonstrates that relatively small amounts of greenwash may foreclose the market and deter a greener firm from entering. Even greater amounts of greenwash may facilitate entry by the green firm, but with its variant perceived as "low quality." The profit-maximizing level of greenwash is driven by the cost of greenwashing, and this section outlines how optimal greenwash responds to changes in the marginal cost of greenwashing. As noted by Lemma 1, increasing the marginal cost of greenwash never results in more greenwash, and if the market is not fully covered, it always reduces it. Greenwashing does not simply affect market structure; it has important implications for consumer welfare and the amount of aggregate environmental harm that arises.

1.4 Implications for Consumer Welfare and Environmental Harm

Greenwashing by an incumbent monopolist serves to make its product more appealing to customers. An incumbent firm greenwashes its product to increase its potential market share and increase its profits. If greenwashing is sufficiently strong, it can foreclose the market to an entrant that may offer a greener product — or even allow entry, but misrepresent its dirty product variant as greener than the entrant's variant. The ability of greenwash to alter the market structure has important implications for

consumer welfare and environmental harm. Some of these effects are straightforward, whereas some are less obvious. Understanding these effects is particularly useful for market regulators and environmental activists who seek to reduce greenwashing behavior by altering its costs.

Consumer welfare, a common interest for market regulators, is given as the (indirect) utility that each consumer enjoys by making their equilibrium consumption choice, summed across the consumers that choose to purchase one of the available variants. Each consumer receives the indirect utility described by Equation 1–1 for purchasing a particular variant i; the level of utility is determined by the price and actual environmental harm caused by that variant. The (falsely) reported level of harm only affects a consumer's welfare through the report's effect on purchase decisions. Figure 1-2 illustrates the effect of greenwashing on the overall level of consumer surplus. It plots consumer surplus against the marginal cost of greenwashing.

Consistent with the results in Hattori and Higashida (2011b), when greenwash does not alter the market structure (and entry occurs), greenwash may benefit consumers. This result arises, because greenwashing serves to intensify price competition between the two firms. Reducing its reported level of environmental harm in the direction of the entrant's actual level of harm decreases the amount of differentiation between the variants, and diminished differentiation results in heighted price competition in the final stage of the game. It is possible that Consumer Surplus achieves local maximum within the Case 1 market structure if the two products are sufficiently differentiated.

Once greenwash is sufficiently strong to alter the market structure — either by securing monopoly status for the incumbent or giving rise to a duopoly in which the incumbent offers the "high quality" product – greenwash generally serves to harm consumers at the margin. In these instances (e.g., in Cases 2-4), greenwash only serves to mislead consumers into making less efficient consumption choices, and intensified price competition is not able to compensate for that negative welfare effect.

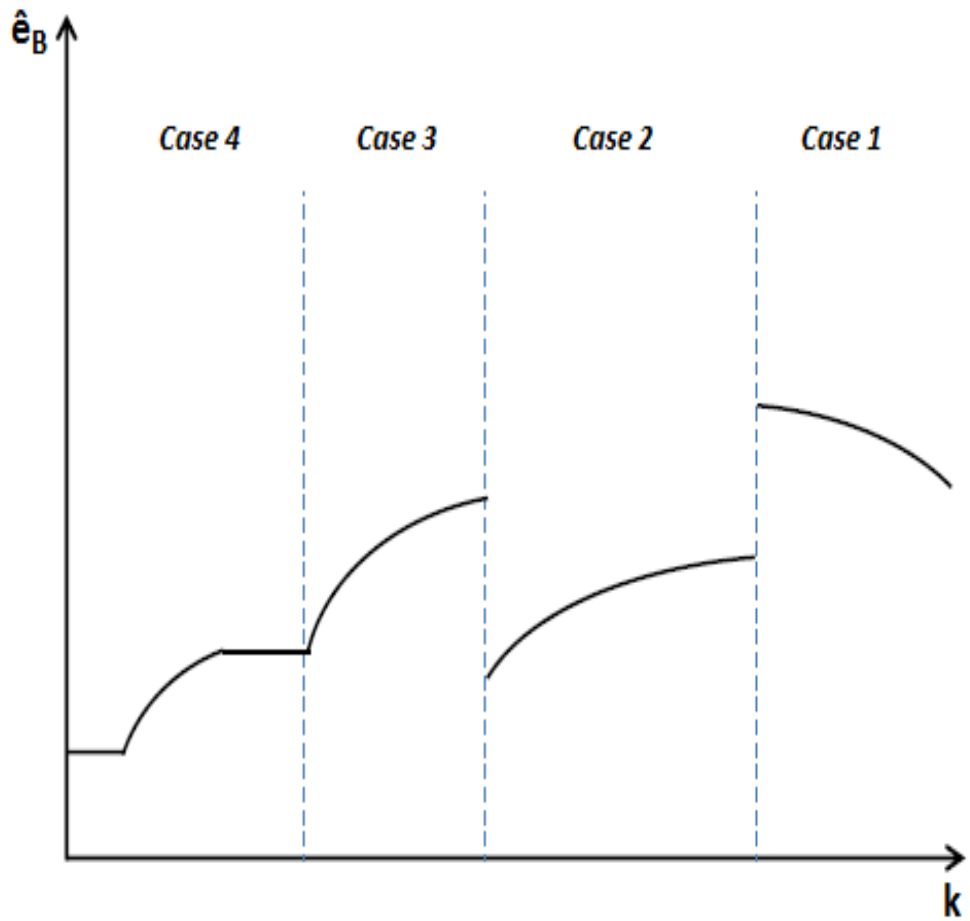

Figure 1-2. The Effect of *k* on Consumer Surplus

Additionally, when the duopoly in which the incumbent offers the “high quality” product arises, greenwash reduces price competition by heightening the level of differentiation between the available variants. If greenwash alters the market structure, it generally reduces consumer welfare. The only exception arises when greenwash is sufficiently strong to facilitate entry by the entrant as the “low quality” firm.

When greenwash is sufficiently large to facilitate entry by the green firm (but as having the “low quality” variant), consumer surplus jumps upward. This discontinuous upward (when viewed in the context of greenwash, as opposed to harm) jump in welfare arises as a consequence of increased price competition. Consumers benefit from entry

by the potential entrant, even when its product is incorrectly viewed as the "low quality" variant. Entry introduces competition in the pricing stage of the game.

The global maximum for consumer surplus arises with some positive amount of greenwash, as greenwash initially benefits consumers. Relatively small amounts of greenwash always benefit consumers, as greenwash (within Case 1) softens price competition. This feature of the model implies that some amount of greenwash is desirable from the consumers' perspective. Given the response of consumer welfare to greenwash advertising and the related changes in the market structure, there are three candidates for the global maximum level of consumer surplus: 1) when $\hat{e_B} = \frac{4e_B - 3e_G}{16}$ results in entry by the green firm, $\hat{e_B} = \frac{4e_B - 3e_G}{16}$ maximizes consumer surplus within Case 1, 2) when $\hat{e_B} = \frac{4e_B - 3e_G}{16}$ does not result in entry by the green firm, a reported level of harm just above the entry threshold level of harm maximizes consumer surplus in Case 1, and 3) a reported level of harm just below the entry threshold level of harm maximizes consumer surplus in Case 4.

Lemma 2. *The global maximum for consumer surplus arises when a positive amount of greenwash is undertaken by the incumbent firm, and the amount of greenwash does not foreclose the market from entry.*

The fixed costs of entry also have important implications for the overall level of consumer surplus. Increasing the amount of fixed costs decreases consumer surplus when it changes the potential entrant's entry decision. As consumers always benefit from entry through increased competition (regardless of how the incumbent positions its variant), increasing the fixed costs of entry is always harmful for consumers.

A separate — and often, equally or more important — issue for market regulators and environmental activists is whether greenwash results in increased or decreased levels of aggregate environmental harm. As in Heijen and Schoonbeek (2008), environmental harm is defined as $\sum Q_i e_i$, over all *i* firms. Figure 1-3 illustrates the

effect of greenwash on aggregate environmental harm. It plots aggregate environmental harm against the marginal cost of greenwashing.

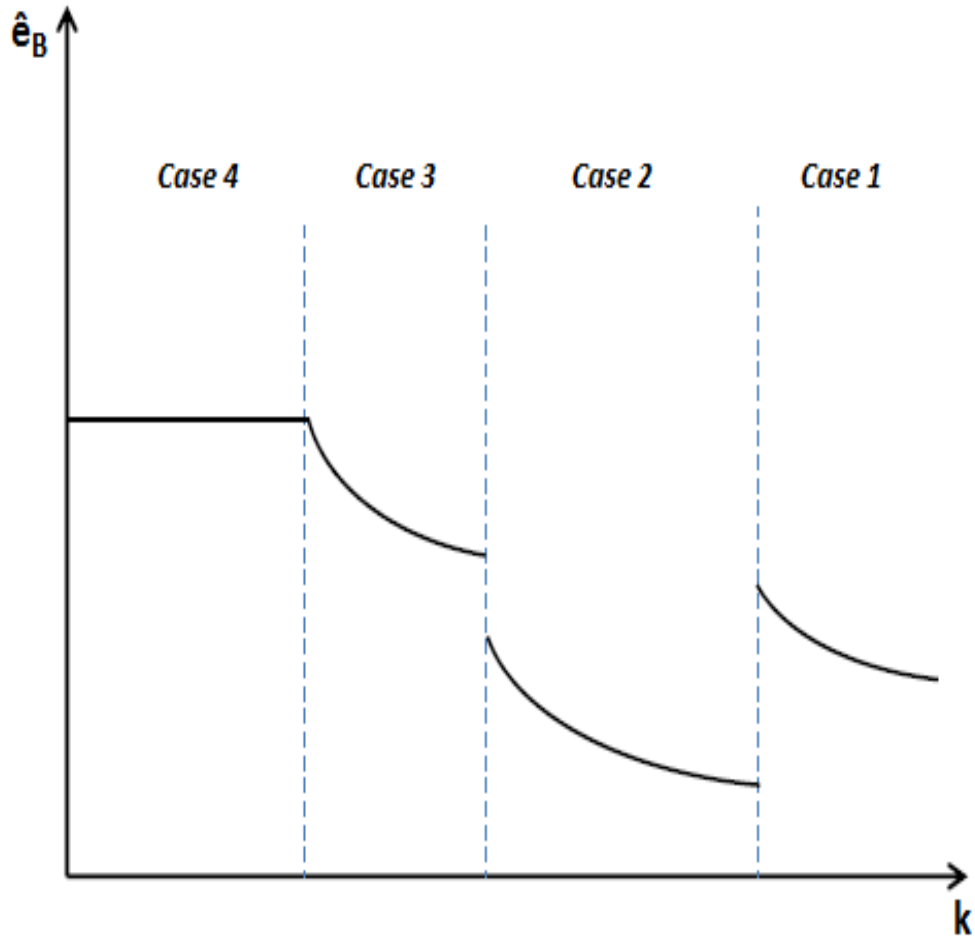

Figure 1-3. The Effect of *k* on Aggregate Environmental Harm

Increasing greenwash generally results in increased aggregate environmental harm, with one possible exception. As shown by Lemma 1, increases in the marginal cost of greenwash do not always reduce the amount of greenwash undertaken by the incumbent firm. When greenwash is just sufficiently high to foreclose the market from entry by the green firm, aggregate environmental harm jumps downward. This downward jump arises, because the total market quantity falls when entry is deterred.

The global minimum for aggregate environmental harm arises when greenwash is just sufficient to foreclose the market from entry by the greener firm.

Lemma 3. *The global minimum for aggregate environmental harm arises when the (positive) amount of greenwash is just above the level that would foreclose the market by the greener firm.*

Any increase in the fixed entry cost may serve to reduce aggregate environmental harm. From the perspective of reducing environmental harm, market regulators or environmental activists may prefer greenwash that is sufficiently high to foreclose the market from entry by the greener firm. As mentioned above, this region is less preferred by consumer-focused regulators. The global maximum for consumer surplus occurs when the market is not foreclosed. Greenwash generally serves to decrease consumer welfare and increase aggregate environmental harm. However, a number of interesting exceptions may affect the desirability of curtailing greenwash. Interestingly, consumer welfare is not maximized, nor is aggregate environmental harm minimized, when greenwash is perfectly prevented. Understanding the responsiveness of a greenwashing firm to changes in its marginal cost may inform those that wish to combat (or facilitate) greenwash.

1.5 Concluding Remarks

The proceeding sections identify and address an existing gap in the current literature relating to false advertising for polluting products. This paper analyzes false advertising behavior by a brown incumbent monopolist in the presence of greener potential entrant when products‘ true polluting properties cannot be readily observed. Such greenwash advertising makes the incumbent’s product more appealing to environmentally conscious consumers, increasing its potential profits. In the presence of positive entry costs, greenwash advertising can also affect entry decisions by potential entrants, affecting the overall market structure. This paper demonstrates that false

advertising may enhance consumer welfare and reduce aggregate environmental harm, demonstrating that some positive amount of greenwash advertising is likely desirable.

Greenwash does not only serve to increase the incumbent firm's market share; it can also alter the overall market structure by foreclosing the market from entry. Market structure effects make analyzing greenwash less straightforward and affect the results considerably. There are instances in which increasing greenwash may benefit consumers and/or decrease aggregate environmental harm. In fact, consumer welfare increases and environmental harm decreases with certain (positive) amounts of greenwash. Consumers benefit when the perceived level of product differentiation is reduced, because price competition becomes more intense. Moreover, aggregate environmental harm falls when greenwash advertising can reduce the number of firms that are present in the market, as less firms implies an overall reduction in the market quantity of the polluting product. Given these structural-driven effects, market regulators and environmental activists must careful consider the likely effects of regulating greenwash advertising. They may not always seek to reduce greenwash.

Combatting greenwash often occurs by increasing its cost – either through legal enforcement by market regulators or activism and advertising campaigns by environmental groups.[14] Effectively eliciting a particular response by a greenwashing firm is not as straightforward as "higher costs result in less undesirable greenwash." Properly combatting (or facilitating) greenwash requires precise knowledge of the market structure and the role that potential entrants play. In the presence of a green potential entrant, aggregate environmental harm increases. Green products attract new consumers to the market, and the environmental impact of the resulting increase in production is not offset by consumers switching to the cleaner variant. Consequently,

[14] The latter affects the firm's cost of greenwashing by making consumers less gullible.

in the presence of a potential entrant, entry-deterring greenwash may be welcomed by environmental groups.

As a point of future research, the model could be adapted to include a probability that greenwash is not successful, or even reduces the incumbent firm's demand through negative reputation effects. This addition, however, would not affect the desirability of a certain positive amount of greenwash advertising. Additionally, a dynamic model, in which consumers learn about the good's harm post-purchase, could be examined. This paper does not consider this case of experience goods; rather, it only considers products whose environmental harm remains unobserved post-consumption, or credence goods.

CHAPTER 2
SPEARS AND DYLAN? CHARACTERIZING THE INCENTIVE TO BUNDLE WHEN MIXED BUNDLING IS NOT FEASIBLE

2.1 Introduction

Music concerts, like any other good, arrive at the marketplace after numerous strategic decisions by their producers. One such strategic decision, or practice, that appears ubiquitous in the concert arena is bundling. This commonly observed pricing strategy, in which firms offer several unique component products as a single combined bundle, is in place every time that multiple acts are placed on the same ticket (e.g., opening acts, joint tours, and festivals). Previous inquiry into this pervasive business practice focuses on the incentive to bundle two (or more) products, but fails to address the composition of an optimal bundle. Deciding whether to bundle two existing products is an important business decision, but a common question in the concert ticket business is: which acts should be bundled? This paper examines the incentive to bundle, but its more important contribution surrounds the identification of an optimal bundle.

Music concerts demonstrate the importance of identifying an optimal bundle. Concerts are routinely bundled into multiple act events, and it stands to reason that the composition of these bundles is not random. Do event promoters bundle similar acts to increase consumers' willingnesses to pay, or do they bundle more differentiated events to draw a larger crowd?[1] This paper answers that question and demonstrates how consumers preferences and capacity constraints may affect the composition of the profit-maximizing bundle.

Bundling can take many different practical forms, but two broad categories of bundling strategies have been identified. Bundles are classified as either pure bundles or mixed bundles. Pure bundles consist of component products that are not available

[1] Consistent with Krueger (2005), I consider promoters to be the profit maximizers. The analysis, however, does not depend on selecting a particular profit maximizer.

for separate purchase. Mixed bundles consist of components that can be purchased as a discounted bundle, or separately. Much of the bundling literature focuses on mixed bundling and demonstrates that mixed bundling is preferred (by a monopolist) to pure bundling for many different product types. Mixed bundling is an effective price discriminating strategy. This practice, however, is rarely observed in concert ticket pricing except for the case of classical music series.

Music concerts are typically offered as a bundle or separately; there is no discount offered to consumers who purchase a ticket to more than one.[2] Mixed bundling may be undesirable in this particular market for two reasons. First, if we are considering sequential acts in a single venue, it may be too costly or infeasible — or even inconvenient to consumers — to clear out the venue between acts and re-check tickets. This explanation is consistent with observing mixed bundling in classical music series, where acts play on separate evenings. Another reason that mixed bundling is not regularly observed in concert ticket sales may be the existence of binding capacity constraints. When capacity is constrained, there is no need to offer tickets to bundled component events separately, because the consumers with the highest willingnesses to pay are already filling all of the available seats. Both practical feasibility and binding capacity constraints may explain the lack of mixed bundling in concert ticket sales.

This paper explores the incentive to bundle events when mixed bundling is not feasible and examines the determinants of an optimal bundle. The remainder of the paper is organized as follows. Section 2 presents a survey of the extant literature. Section 3 develops a model of horizontally differentiated products, in which consumers exhibit concave transportation costs. It considers a monopolist's optimal pricing and

[2] I acknowledge that a discount could be offered for consumers that attend one concert on Friday night and another on Saturday night, but this practice is rarely observed outside of classical music series.

bundling strategies when the component products locations are exogenously assigned, and then, considers the same incentives when the component products locations are endogenously selected. I demonstrate that the incentives to bundle products are dependent both on the level of differentiation between the components and on the degree of additivity of consumers utility functions. Lastly, I examine the effect of capacity constraints on the incentive to bundle, finding that the unique structure of a particular constraint determines whether it reduces or intensifies the incentive to bundle.

2.2 Extant Literature

Much of the previous literature on bundling incentives focuses on the relationship between the products, or more specifically, on the relationship between consumers" willingnesses to pay for them. Early work by Adams and Yellen (1976) and Schmalensee (1984) demonstrate that a monopolists incentive to bundle is stronger when consumers willingnesses to pay for the two component products are inversely related. Schmalensee (1982) also shows that mixed bundling is a better price discrimination mechanism than pure bundling. When consumers valuations for two products are inversely related, the monopolist can incentivize more consumers to purchase both products by bundling them into a single product. Moreover, by offering a discounted bundle, alongside separately sold component products, the monopolist can enjoy the price discriminating effect of bundling without losing consumers whose net valuation for one of the components is positive, but whose net valuation of the bundle is negative.

The incentive to bundle can also be greatly affected by whether the products are complements, substitutes, or unrelated goods. Reservation values for complements are superadditive, while reservation values for substitutes are subadditive, or inversely related. Guiltinan (1987) shows that firms are more likely to (purely) bundle complementary goods, because their reservation values are strictly superadditive. Vankastesh and Kamakura (2003), however, present more nuanced results. They demonstrate that pure bundling is optimal for strong complements, and selling components separately is

optimal with strong substitutes. They find that pure bundling is strictly suboptimal (when also considering mixed bundling) for substitutable goods.

Each of the above papers describes circumstances under which pure bundles, mixed bundles, or individually sold components are optimal strategies for the monopolist, but none consider the construction of an optimal bundle. Some more recent marketing research (See, for example, Bradlow and Rao (2000) and Chung and Rao (2003)) has attempted to apply product design and attribute theory to bundle design, but their approaches have difficulty measuring the degree of heterogeneity between bundle components and characterizing the substitutability between components. The current paper examines the incentive to bundle horizontally differentiated components, identifies an optimal bundle design, and describes the role of both product differentiation and additivity of consumers' utility in determining these incentives.

This paper makes a number of meaningful contributions to the theory of horizontally differentiated products and bundling. First, the model examines both the incentive to bundle two component products and the design of an optimal bundle. It also focuses on products that cannot be sold as a mixed bundle, such as admission to events. As most studies point to the desirability of mixed bundling as the profit-maximizing strategy, this approach shines light on a group of products that are often neglected by the bundling literature. This paper also considers the potential for multi-purchasing and concave transport costs in a Hotelling model, which have unfortunately been understudied. Section 3 continues with the construction an analysis of the model.

2.3 The Model

The model examines the incentive to bundle horizontally differentiated products when mixed bundling is not feasible. When bundling is desirable, and a continuum of components is available, the model identifies the seller's profit maximizing bundling strategy. The analysis in this section is presented in the context of concert bundling, but it generalizes to any bundling situation in which mixed bundling is not possible. In

particular, it generalizes to any scenario in which admission fees are charged for entry into an event such as film festivals and wine tastings.

The market is characterized by a monopolist seller who can choose between hosting and selling admission to two separate events, E_1 and E_2, or hosting a single combined event, E_{12}. The combined event E_{12} is simply a bundle of component acts E_1 and E_2. There are no marginal costs of production included in the model. For entertainment events (e.g., concerts or film festivals), zero marginal cost is a reasonable assumption. Fixed costs are not explicitly treated in the model, but as they are likely to be higher when the two events are offered separately, including them would only intensify the incentives to bundle that are examined throughout the remainder of the paper.

The seller maximizes profits by choosing whether to bundle the two events, selecting the (horizontal) location of the two events, and choosing the price for the product(s) offered simultaneously. Analytically, the decision, or incentive, to bundle the two events is determined by which option offers the largest profits, given that the locations of the events and the admission prices would maximize the seller's profits in either case. It is, thus, irrelevant to consider whether the bundling choice is made ex ante. The focus of the proceeding section is to identify whether the monopolist has an incentive to bundle and if so, what component events it should optimally bundle.

Consumers differ in their horizontal preferences over the potential events. For example, in the context of music concerts, some consumers prefer rock music while others prefer folk music. Consumers' preferences over the potential events are uniformly distributed along a Hotelling line, and the utility derived by a consumer with preference location θ_i from attending a single-component event E_j located at l_j is given as:

$$U_{i,j} = V - |l_j - \theta_i|^{.5}, \tag{2–1}$$

while a consumer with preference location θ_i that consumes both events E_1 and E_2, either as a bundle or separately derives utility:

$$U_i = (1+\alpha)V - |l_1 - \theta_i|^{.5} - |l_2 - \theta_i|^{.5}. \tag{2–2}$$

where V is the gross valuation that a consumer receives from attending any single-component event, and $\alpha \in [0, 1]$ measures the desirability of attending a second event. The above utility function assumes that the consumers' gross valuation of attending multiple events is weakly subadditive. That is, the gross valuation of attending a second event is either less than or equal to that of the second. This specification is adopted to capture the notion that a portion of the utility derived from a attending a particular event is not location-specific — consumers may simply enjoy attending an event — and that portion of the gross valuation is likely declining in the number of events a consumer attends. The disutility that a consumer receives from attending a non-ideal event (i.e., an event that is not perfectly aligned with the consumer's preferences) is assumed to be concave in the difference between the consumer's preferences and the horizontal location of the event.

The concavity of "transport costs" assumption is supported by two related, practical considerations. [3] First, consumers are more aware of differences between events that are closer to their own preferences. A fan of American folk music is more likely to distinguish between a Bob Dylan and a Willie Nelson concert than between a Madonna and Kylie Minogue. Fans of 1980s pop music would likely make the reverse distinction. Second, when two differentiated products are bundled, concavity of transport costs implies that consumers whose ideal component forms part of the bundle is more likely

[3] The disutility that a consumer receives from attending a non-ideal event is referred to as "transport costs" in the literature related to horizontal product differentiation à la Hotelling. See, for example, d'Aspremont, Gabszewicz, and Thisse (1979), Economides (1986), and Cremer, Marchand, and Thisse (1991).

to consume the product than a consumer whose ideal component is located between the two components that form the bundled event. That is, with concave transport costs, an avid fan of one component act is more likely to attend a bundled concert than a moderate fan of both acts.

It is also worth noting that there is no incentive to bundle in the presence of convex transport costs, making such an assumption irrelevant to the current analysis. With convex transport costs, a monopolist always earns more profit by offering component events separately. Bundling components never increases demand.

Thoroughly characterizing the firm's optimal price and bundling strategies requires an investigation under both exogenous and endogenous location assumptions. These two assumptions address different practical situations; neither is more realistic than the other. Under an assumption of exogenous locations, I investigate bundling choices when the product offering is already determined. For example, a winery that produces Pinot Noir and Cabernet Franc faces the choice of selling tastings for each separately (as is common at Canadian wineries) or as a "flight" (as is more common at California wineries). Similarly, an entertainment firm that manages two acts whose concert tours will pass Tampa, Florida on the same weekend must choose whether to host separate events or combine the shows into a bundled event. Under both scenarios, the level of horizontal differentiation between the two products has already been selected when the price and bundling strategies are selected. Under an assumption of endogenous locations, I consider bundling decisions when the products variants can be selected from a pool of potential products. For instance, the winery may have a large number of different varietals (or even different offerings within a single varietal) from which to design its tasting. It would be able to choose the level of differentiation between the two wines that is offers and whether to price them separately or together. Similarly, the entertainment firm may manage many acts and be able to select which acts to offer in Tampa. The ability of the firm to select the level of differentiation between its

product offerings determines the applicability of an exogenous or endogenous locations assumption. Below I consider price and bundling strategies under both assumptions.

Exogenous Product Locations: Components Sold Separately

Identifying the monopolist's incentive to bundle differentiated products requires a characterization of the profits associated with selling the components separately. Bundling is only desirable if it yields higher profits than selling the components separately. This subsection describes the monopolist's profit-maximizing pricing strategy when it does not bundle under the assumption of exogenous product locations. I modify the traditional Hotelling model to allow for the potential of multi-purchasing by a subset of consumers, identifying those consumers who will purchase both events even when they are priced and sold separately.

To begin, I identify the demand for each unbundled component. The demand for a particular component event is dependent on the location of both component events, because consumers can engage in multi-purchasing. If the components are not sufficiently different, some consumers choose to attend both events. When the components are sufficiently differentiated, however, no consumer chooses to attend both events.

If the events are sufficiently similar, some consumers will attend both events even when they are offered separately. Figure 2-1 depicts the demand relation in the presence of multi-purchasing. Depending on the level of differentiation between the two events, it is possible that those consumers for whom one of the components represents their ideal event engage in multi-purchasing (Panel 1a), or only a group of consumers whose ideal event lies between the two component events engage in multi-purchasing (Panel 1b). In both cases, the consumer whose preferences place them at the midpoint of all purchasing consumers are the most likely to engage in multi-purchasing. Following the intuition laid out by Anderson et. al. (2010), multi-purchasing in a Hotelling setting arises when a consumer may receive positive utility from consuming a second variant

after they have purchased their most preferred variant. The independent choices to purchase each variant are only linked through the degree of additivity of utilities. When preferences are strictly subadditive (i.e., $\alpha < 1$), the choice to purchase the "second" variant is only affected by consumption of the "first" variant through the reduction in the gross valuation (i.e., from V to αV).[4] In the context of attending an event, this implies that if a consumer has a valuation of attending an event, and if that valuation is decreasing in the number of events they attend, the first event that a consumer chooses to attend only affects consumption of the second by reducing the consumer's interest in attending an event. Prices, however, do not have a competitive effect between the events.

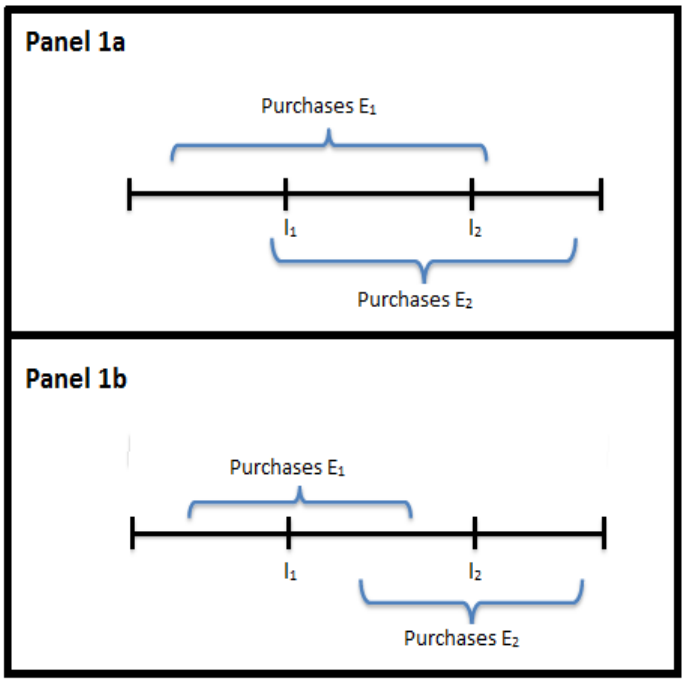

Figure 2-1. Multi-purchasing

[4] Here, "second" means less preferred, and "first" means more preferred. It is not necessarily linked to the order in which the products are consumed.

The potential for multi-purchasing gives rise to a discontinuity in the demand function when the preferences across the two components are strictly subadditive. When multi-purchasing occurs, some consumers of each event have the reduced gross valuation of attending that event, because it is their second event. As a result, the demand for component event E_i is given as:

$$D_i(p_i, p_j, d) = \begin{cases} (V - p_i)^2 + (\alpha V - p_i)^2, & \text{if } d < (\alpha V - p_i)^2 + (\alpha V - p_j)^2 \\ 2(V - p_i)^2, & \text{if } d \geq (\alpha V - p_i)^2 + (\alpha V - p_j)^2 \end{cases} \tag{2–3}$$

where d is the degree of horizontal differentiation between E_1 and E_2 (i.e., $d \equiv l_2 - l_1$).[5] When the components are sold separately, cross-price effects only arise through the effect of pricing on multi-purchasing. If the price of one event increases, it becomes less likely that any consumer chooses to purchase both products. Increasing the degree of horizontal differentiation between the two events has a similar effect. Additionally, if there are some consumers that do attend both events, decreasing α below 1 reduces the demand for both events. That is, whenever the two events share some attendees, and the gross valuation of attending an event is strictly subadditive, demand for each event is decreasing in α.

In order to characterize the monopolist's pricing strategy, I must consider their behavior both when the level of differentiation between the two events is low enough to facilitate multi-purchasing and when it is not. I pay particular attention to the monopolist's pricing behavior around the multi-purchasing threshold.

Multi-purchasing only arises when 1) the component events are sufficiently similar, and 2) consumers' valuation of attending a second event is sufficiently large. As products become more differentiated, and as consumers derive less utility from

[5] For simplicity, assume E_2 is located to the right of E_1 on the Hotelling line. That is, $l_2 - l_1 > 0$.

attending a second event, the monopolists' ability to sell both events to a subset of consumers becomes less likely. The effect of differentiation is straightforward and follows directly from the conditional statements in the piece-wise demand function. The pricing strategy, conditional on the level of horizontal differentiation between the two events, is characterized as follows:

$$p_i* = \begin{cases} \frac{2+2\alpha-\sqrt{2(4\alpha-1-\alpha^2)}}{6}V, & \text{if } d < (\alpha - \frac{1}{3})^2 V^2 \\ \frac{V}{3}, & \text{if } d \geq (\alpha - \frac{1}{3})^2 V^2 \end{cases} \tag{2–4}$$

We can see that the monopolist sets its per-component price at $p_i = \frac{v}{3}$ henever $\alpha \leq \frac{1}{3}$. For such strongly subadditive preferences, the monopolist maximizes profits by separating consumers into two distinct marketplaces. No consumers engage in multi-purchasing, regardless of the similarity between the two component events.

The effect of α on the profit-maximizing pricing strategy in the presence of multi-purchasing is less straightforward, as it introduces an interesting tradeoff for the monopolist to evaluate when selecting its pricing strategy. The monopolist benefits from multi-purchasing behavior, as it provides the monopolist with a larger base of potential consumers. It, however, also faces the consequence that the gross valuation of an event is reduced for mass of its customers. That is, the number of potential consumers of each event is increasing, but the average gross willingness to pay is falling. This tradeoff gives rise to some an interesting relationship between the marginal gross valuation of attending a second event and the profit-maximizing pricing strategy. Figure 2-2 presents this relationship.

It can be seen easily that $p_i* = \frac{V}{3}$ for $\alpha < \frac{1}{3}$. More interestingly, for $\alpha \in \left[\frac{1}{3}, 2-\sqrt{2}\right]$, p_i* is decreasing in α. Over this range, the profit-maximizing pricing strategy, given that the multi-purchasing condition is satisfied, is characterized by falling prices as consumers' willingnesses to pay for a second event increase. While a greater desire to attend a second event increases the number of potential consumers for both events

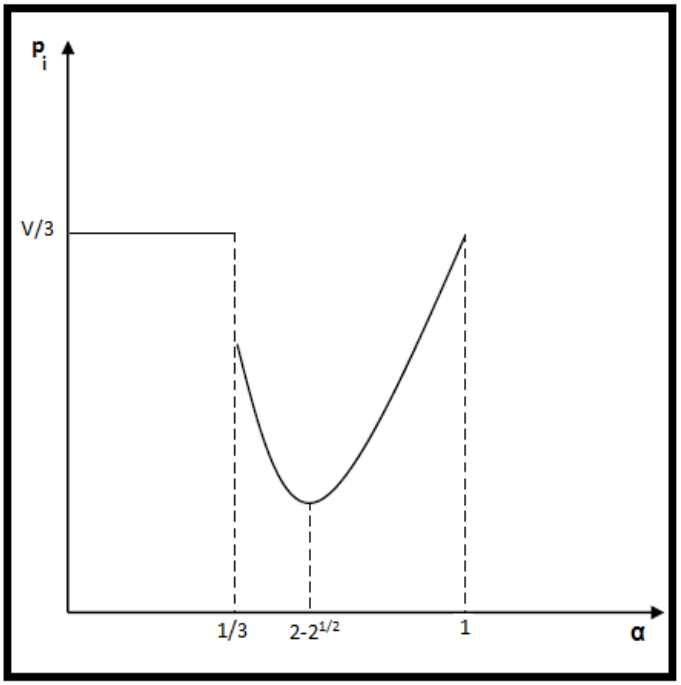

Figure 2-2. Component Pricing

through more common multi-purchasing, the average valuation of an attendee falls, placing downward pressure on prices. Once $\alpha > 2 - \sqrt{2}$, however, further increases in the valuation of attending a second event place upward pressure on the price of both separately sold events.

Exogenous Product Locations: Bundled Components

Identifying the monopolist's incentive to bundle differentiated products requires a characterization of the optimal bundling strategy and a comparison of the profits associated with that strategy to the profits that are earned when the events are sold separately. Above, I identify the monopolists' profit-maximizing behavior when events are priced and sold separately. I must now identify the optimal pricing decision when the component events are offered as a bundle. I characterize the incentive to bundle as a function of both the degree of differentiation between the component events and the level of additivity of consumers' utilities.

To begin, I characterize the relationship between consumers' preferences for the bundled product and the degree of horizontal differentiation between the component events. The two consumers whose ideal events are included in the bundle (i.e., the consumers located at l_1 and l_2) receive the greatest utility from consuming the bundled product.[6] This implies that demand is only positive when the bundled price, p_{12}, and degree of differentiation are such that $(1+\alpha)V - \sqrt{d} - p_{12} > 0$. Additionally, of the consumers with tastes located between l_1 and l_2, the consumer located at $\frac{l_1+l_2}{2}$ receives the least utility from consuming the bundled product, implying that subset of consumers located between l_1 and l_2 abstain from purchasing the bundled product when $(1+\alpha)V - 2\sqrt{\frac{d}{2}} - p_{12} > 0$. As a consequence, when the price or degree of differentiation increases above a particular threshold, some consumers located between l_1 and l_2 choose not to purchase the bundled product, but those consumers located at and near l_1 and l_2 continue to purchase the bundle. As a result, the demand for the bundled event is given by the following piece-wise function:

$$D_{12}(p_{12}, d) = \begin{cases} \frac{d^2}{2[(1+\alpha)V-p_{12}]^2} + \frac{[(1+\alpha)V-p_{12}]^2}{2}, & \text{if } p_{12} \leq (1+\alpha)V - 2\sqrt{\frac{d}{2}} \\ \frac{d^2}{2[(1+\alpha)V-p_{12}]^2} + \frac{[(1+\alpha)V-p_{12}]^2}{2} & \\ -[(1+\alpha)V - p_{12}]\sqrt{2d - [(1+\alpha)V - p_{12}]^2}, & \text{if } p_{12} > (1+\alpha)V - 2\sqrt{\frac{d}{2}} \end{cases} \tag{2–5}$$

Figure 2-3 provides a graphical representation of the relationship between consumers' tastes and component characteristics. Panel A depicts the case in which the component events are not sufficiently differentiated to deter consumption by a set of consumers located between l_1 and l_2. Panel B depicts the case in which the component events are sufficiently differentiated. Both panels graph the location of the bundled product (L) and consumers' individual preferences over the horizontally differentiated product attributes

[6] his feature follows from the assumption of concave transport costs.

in the l_1, l_2-plane. Consumers are uniformly distributed along the 45-degree line, as the tastes of a given consumer i, θ_i, do not differ in their relation to the locations of the two component events. Those consumers that choose to purchase the bundle are identified by the darkened portion of the 45-degree line. Comparing the two panels, it is clear that increasing k above zero initially increases demand, but decreases after crossing a critical threshold.

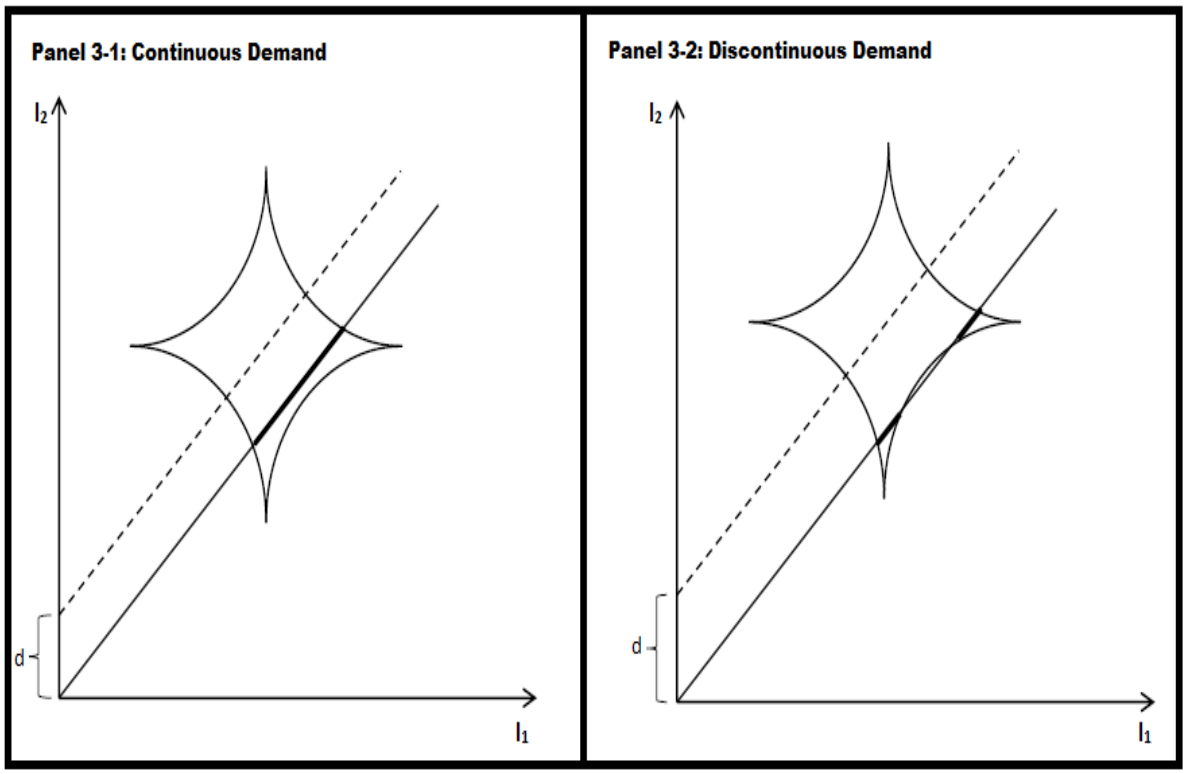

Figure 2-3. Bundle Demand

The monopolist maximizes profits by selecting the bundled price, p_{12}, according to:

$$\max_{p_{12}} \quad \pi_{12} = p_{12} D_{12}(p_{12}, d) \tag{2–6}$$

The monopolist sets the bundled price such that the consumer whose preferences are located at the midpoint between the two component event locations receives no consumer surplus. The profit function is non-differentiable at the kink in the demand function. It is, however, monotonically increasing in p_{12} when $p_{12} < (1+\alpha)V - 2\sqrt{\frac{d}{2}}$

and monotonically decreasing in p_{12} when $p_{12} > (1+\alpha)V - 2\sqrt{\frac{d}{2}}$, implying that $p_{12} = (1+\alpha)V - 2\sqrt{\frac{d}{2}}$ maximizes the monopolist's profits.

If the monopolist chooses to bundle the two component events, it earns $\pi_{12} = \frac{5d}{4}\left[(1+\alpha)V - 2\sqrt{\frac{d}{2}}\right]$. Comparing the potential profits associated with bundling the component events to those earned when the events are offered separately, it can be seen that the incentive to bundle is dependent on the degree of horizontal differentiation between the two events and the marginal valuation of attending a second event. The following discussion regarding the incentives to bundle is presented as follows. For given ranges of α, the degrees of exogenously determined product differentiation that provide an incentive to bundle will be characterized. These relationships are also presented in Figure 2-4.

$\alpha < 0.769$: For low values of α, the monopolist always earns more profits selling admission to the two events separately. When, consumers do not place a high value on attending a second event, the monopolist is better off selling admission separately, regardless of the degree of product differentiation between the two events. Interestingly, this range of α includes the range of *d* over which the profit-maximizing price of admission to each event is decreasing in α.

$0.769 < \alpha < 0.857$: Within this range of α, a single range of d over which the monopolist has an incentive to bundle the events arises. This range is bounded to the left and right, such that we may define it as $[\underline{d}, \bar{d}]$, and $d > 0$. For very similar events (i.e., $d < [\underline{d})$, the monopolist earns greater profits by pricing admission separately and allowing a subset of consumers to engage in multi-purchasing. For sufficiently differentiated events (i.e., $d > \bar{d}$), the monopolist earns greater profits by pricing admission separately at $p = \frac{V}{3}$ and eliminating the possibility for multi-purchasing.

$0.857 < \alpha < 0.884$: Within this range of α, two unique ranges of d over which the monopolist has an incentive to bundle the events arise. Similar to the ranges described directly above, the monopolist is better off pricing two events that are characterized

by very small and very large degrees of differentiation separately. Within this range of α, however, there is also a third range of d in which the monopolist does not choose to bundle the two events. This third range arises due to the upward jump in the profit-maximizing pricing strategy (when the component events are sold separately) when d is sufficiently large to prevent multi-purchasing. Within this range of α, that upward jump is large enough to make bundling locally unprofitable.

$\alpha > 0.884$: Within this range of α, as with $0.769 < \alpha < 0.857$, a single range of d over which the monopolist has an incentive to bundle the events arises. The value of attending a "second" event is sufficiently high to make bundling profitable, even for degrees of horizontal differentiation that would give rise to multi-purchasing in the absence of product bundling.

When consumers do not place a high value on attending a second event (i.e., α is particularly small), bundling is not profitable. The monopolist earns higher profits selling the two products separately. Only when $\alpha > 0.769$ can bundling be profitable; the monopolist sells sufficiently similar or sufficiently different component events separately, but offers moderately differentiated events as a bundle.

The remainder of this section considers the effect of endogenizing the degree of product differentiation between the two events. This modification to the model addresses the issue of constructing the optimal bundle. I characterize the optimal degree of horizontal differentiation as a function of the additivity of consumers' utilities.

Endogenous Product Locations: Components Sold Separately

As was demonstrated above, the monopolists' profits are reduced when the products are sufficiently similar to give rise to multi-purchasing by a subset of consumers. The monopolist can avoid suffering these reduced profits when consumers' preferences are not strictly additive by increasing differentiation. When $\alpha < 1$, the monopolist enjoys an increased willingness to pay for its component events if the degree of horizontal differentiation becomes sufficiently strong to deter any consumer from

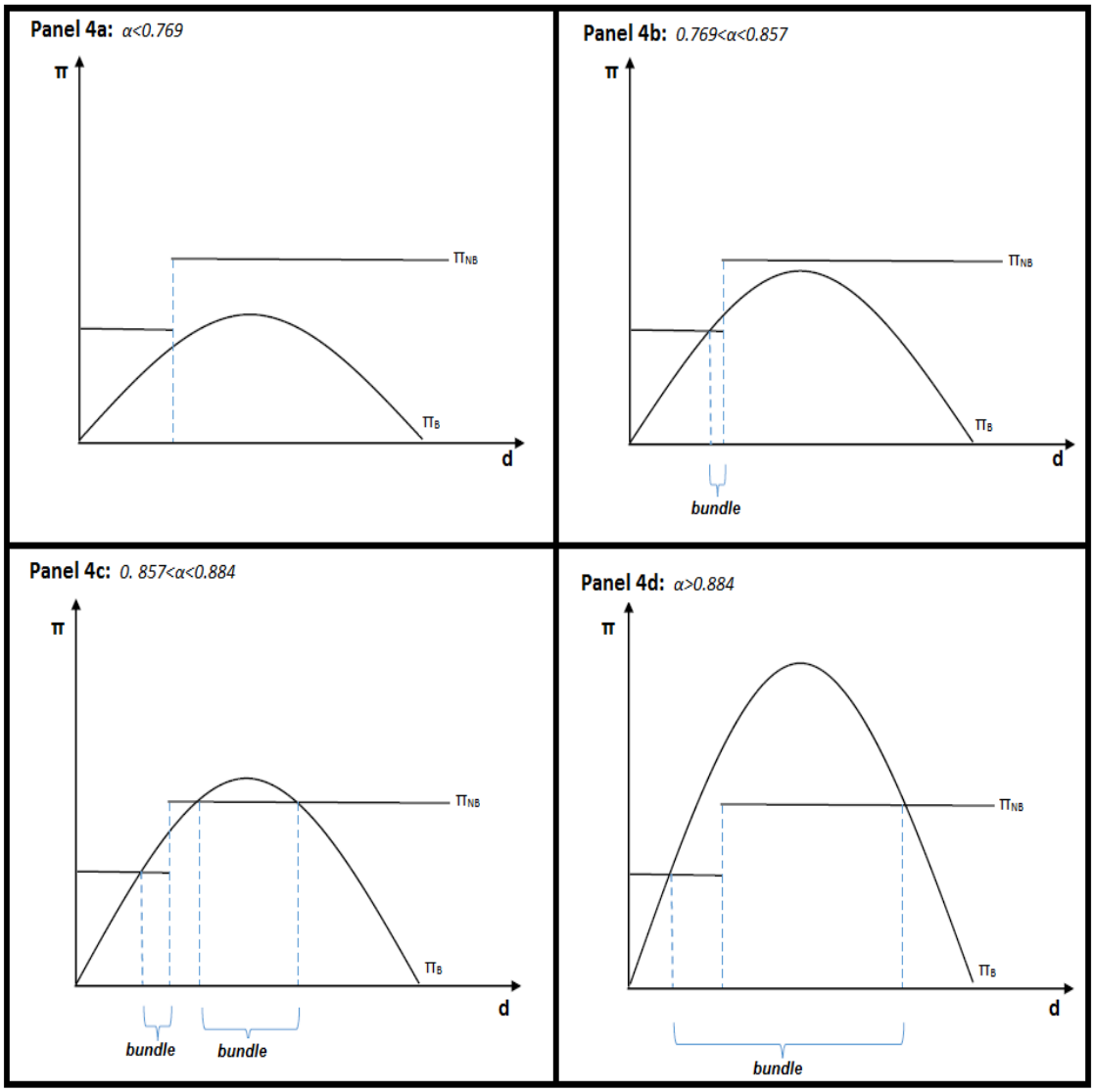

Figure 2-4. The Incentive to Bundle

purchasing both products.[7] That is, the monopolist increases its own profits by setting $d > (\alpha - \frac{1}{3})^2 V^2$. The profit-maximization problem for the monopolist that sells component events separately is simplified to:

$$\max_{p_i} \quad \pi_i = 2p_i(V - p_i)^2 \tag{2–7}$$

[7] I explain that the profits associated with the case of strict additivity of preferences (i.e., $\alpha = 1$) results in the same level of profits when the events are not bundled below.

The firm sets a price of $p_1 = p_2 = \frac{V}{3}$ for each of its events and sells $D_1 = D_2 = \frac{8V^2}{9}$ units of each event. Consequently, the monopolist earns total profits (across the two events) equal to $\pi = \frac{16V^3}{27}$. This level of profits arises for any degree of differentiation between the two events above a critical threshold maximizes profits. Profits are constant for any *d* that satisfies this threshold.

When consumers' preferences across the two events are strictly additive, the resulting profits equal those obtained above. In this particular case, demand simplifies to $D_i(p_i) = 2(V - p_i)^2$, which is identical to the portion of the demand curve on which the monopolist operates above. The only distinction between strict subadditivity and strict additivity of preferences is that in the case of strict additivity, the monopolist does not have to satisfy a minimum level of differentiation between the two events. Any level of differentiation results in profits equal to $\pi = \frac{16V^3}{27}$.

Endogenous Product Locations: Bundled Components

If the monopolist chooses to bundle the two events, regardless of the degree of differentiation between the component events, the monopolist maximizes profit by setting $p_{12} = (1+\alpha)V - 2\sqrt{\frac{d}{2}}$. Thus, the monopolist' maximization problem can be stated as:

$$\max_{d} \quad \pi_{12} = \frac{5d}{4}\left[(1+\alpha)V - 2\sqrt{\frac{d}{2}}\right] \tag{2–8}$$

The monopolist maximizes profit by setting $d* = 2\left(\frac{(1+\alpha)V}{3}\right)^2$ and $p_{12}* = \left(\frac{(1+\alpha)V}{3}\right)$ and earns a profit of $\pi_{12}* = \frac{10}{4}\left(\frac{(1+\alpha)V}{3}\right)^3$. Comparing the maximum profits associated with bundling and those associated with selling the component events separately, the incentive to bundle becomes quite simple. If the monopolist is able to select the degree of differentiation between the two component events, it chooses to bundle the two events when consumers sufficiently value attending a second event, when $\alpha > 0.857$. That is, the maximum profits that it can earn when bundling the two events exceeds those it can earn when the events are price separately if consumers exhibit a strong desire to attend a second event.

Interestingly, when the monopolist chooses to bundle the two events, it sets a degree of differentiation greater than that which it might select if it sells the component events separately. The profit maximizing degree of differentiation when the events are bundled is greater than the threshold level that was established above when considering separately priced events. This result implies that, depending on the values of consumers' gross valuation of attending a second event, it is possible to see two events that are more closely aligned offered separately, while some more differentiated ones could be offered as a bundle.

Proposition 2.1. *When the degree of differentiation (i.e., horizontal location) is endogenously selected, the monopolist offers more differentiated components when components are bundled than it would if components are sold separately. Alternatively stated, a monopolist that bundles offers more product diversity than would be offered within a duopoly market.*

In this section, I have characterized a monopolist's pricing and bundling incentives when it offers two horizontally differentiated products and faces consumers with concave transport costs. Bundling only arises as a profit maximizing strategy when consumers derive a sufficiently large amount of utility from attending a second event, and that threshold level is most strict when the monopolist endogenously chooses the degree of differentiation between the two products. When the degree of product differentiation is exogenously determined, bundling is never observed when $\alpha < 0.769$. When consumers' marginal gross valuation of attending a second event rises above this threshold, the monopolist chooses to bundle moderately differentiated products. Very similar and very dissimilar products are offered separately. When the degree of differentiation between the two products is endogenously chosen by the monopolist, bundling only arises if $\alpha > 0.857$. Interestingly, when this threshold is not met, the monopolist may choose to offer two events separately that are less differentiated than the bundle that is offered when the threshold is met.

2.4 Extension: Capacity Constraints

When considering events as the products being bundled, a logical extension is to consider the effect of capacity constraints. Courty (2003) claims that 39% of all shows sell out, implying that a binding capacity constraint has been met — unless, of course, the profit-maximizing quantity supplied just equals the size of the constraint. In the preceding section, bundling allowed the monopolist to extract additional surplus from each consumer and increased the overall number of consumers purchasing. A natural question to ask is whether limiting the extent to which bundling can be used to attract additional consumers diminishes the incentive to bundle. This section demonstrates that that is not the case; to the contrary, capacity constraints may, in fact, intensify the incentive to bundle.

Capacity constraints can be applied to events in two distinct ways: 1) to each product (separately), or 2) to the overall market quantity (jointly). The first method of applying a capacity constraint would entail constraining each unbundled component at the same level as the bundled product, whereas the second would entail constraining the sum of the unbundled components at the same level as the bundled product. Any binding constraint on quantity, regardless of how it is applied to unbundled components, affects the pricing and composition of the profit-maximizing bundle. The monopolist still sets the price and degree of differentiation such that the consumer located at $\frac{l_1+l_2}{2}$ is indifferent between purchasing the bundle and not purchasing the bundle (i.e., that consumer receives zero consumer surplus). If the capacity constraint is set at k, this implies that the profit-maximizing degree of differentiation is d*=4k/5, and price is $p_{12}* = (1+\alpha)V - 2\sqrt{\frac{2k}{5}}$. When the capacity constraint binds, the profits associated with bundling are given as $k[(1+\alpha)V - 2\sqrt{\frac{2k}{5}}]$. As a result, tightening the quantity restriction decreases the degree of differentiation and increases the price of the bundled product.

As the total output associated with bundling is greater than that of unbundled components, capacity constraints initially affect only the profits associated with bundling.

Capacity constraints that only bind when the component events are bundled must reduce the incentive to bundle. It is less obvious what happens when the constraint binds for unbundled components as well. By adopting one of the types of quantity restrictions mentioned above, it is possible to fully characterize the effect of capacity constraints on the incentive to bundle — including when capacity constraints affect the pricing of unbundled components.

Capacity Constraints Imposed on Unbundled Components Separately

Capacity constraints may be imposed such that each individual component faces the same constrained quantity as the bundle. This type of quantity constraint is likely to arise with music concerts, in which the constraint is imposed by the size of the venue. If two (bundled) acts are scheduled at the Tampa Theatre on Friday night, the maximum quantity of tickets that may be sold is constrained by the number of seats. If the two acts were offered as unbundled components, with one act playing Friday night and one playing Saturday night, each event is independently constrained by the number of seats in the theatre. When each act is offered separately, each may take advantage of the full size of the venue; the quantity sold of the bundled event could not exceed that same occupancy limit.

For capacity constraints that are sufficiently large to bind only the bundled quantity, the incentive to bundle is maintained if: $k[(1+\alpha)V - 2\sqrt{\frac{2k}{5}}] > \frac{16V^3}{27}$. When the constraint is restrictive enough to bind the quantity of unbundled components sold as well (i.e., $k < \frac{8V^2}{9}$), the monopolist chooses to bundle if:

$$\max_{d} \quad \pi_B - \pi_{NB} = k\left[(1+\alpha)V - 2\sqrt{\frac{2k}{5}} - 2V + 2\sqrt{\frac{k}{2}}\right] > 0. \tag{2–9}$$

The relationship between the quantity restraint and the additivity of consumers utility is depicted in Figure 2-5.[8] The shaded region is comprised of all combinations of α and $\hat{k}$ that maintain the incentive to bundle. Two interesting points arise out of this analysis. First, there is no binding constraint that that does not reduce the bundling incentive, relative to the unconstrained equilibrium. The minimum level of additivity that maintains the incentive to bundle is $\alpha > 0.859$, compared to $\alpha > 0.857$ in the unconstrained equilibrium. Second, tightening the restraint beyond $k = \frac{8V^2}{9}$ always reduces the incentive to bundle. That is, maintaining the incentive to bundle requires a higher value of α. This result is rather intuitive. If the monopolist is able to offer the two events as two separate products (unbundled components) and ease the effect of the capacity constraint, tightening the quantity restraint makes it more likely to do so.

Capacity Constraints Imposed on the Sum of Unbundled Components

It is also reasonable to consider how the incentive to bundle is affected when the capacity constraint binds the sum of output (across the two unbundled components). Constraints may apply in this was for multi-venue or multi-stage events. Suppose, for example, that the Gasparilla Music Festival in Downtown Tampa can sell tickets to events on two different stages separately or jointly. Assuming that consumers will self-separate to fill each venue, the quantity constraint would apply not to the individual stages, but the total across the two. Regardless of whether admission to the two parks is sold as a bundle or unbundled components, a quantity constraint would apply to the sum of products sold.

When the overall market quantity of unbundled products is constrained at the same level of the bundle, and the constraint is restrictive enough to bind the quantity of

[8] In order to simplify the graphical representation, I have placed an adjusted quantity constraint on the horizontal axis, where $\hat{k} \equiv \frac{k}{V^2}$.

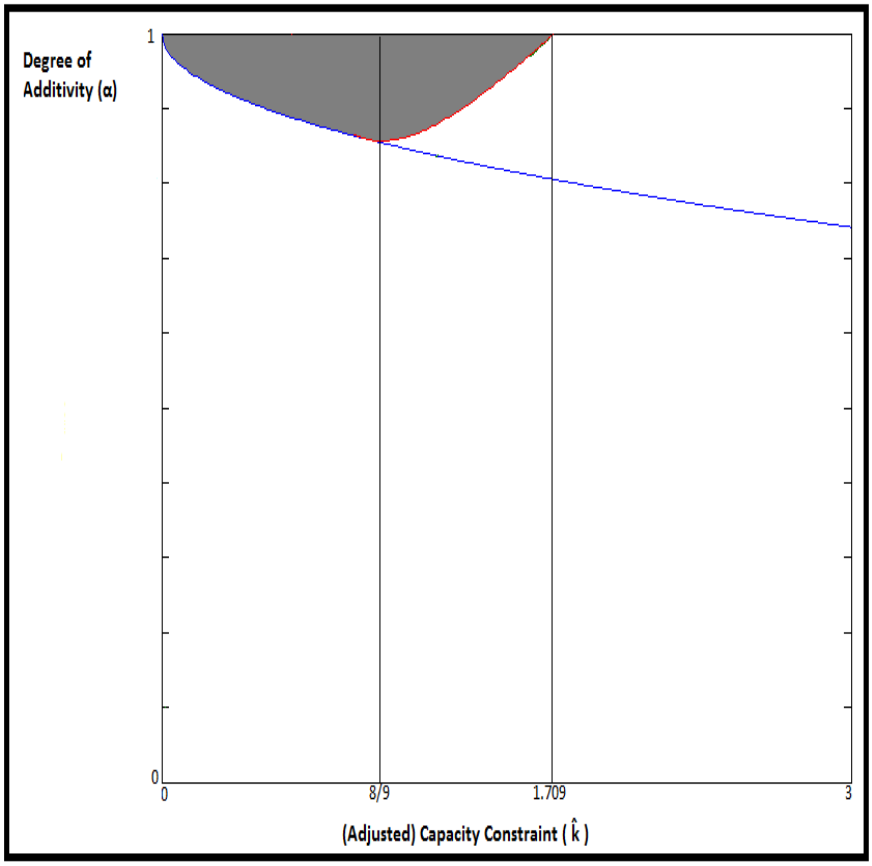

Figure 2-5. Capacity Constraints Imposed On Unbundled Components Separately

unbundled components sold (i.e., $k < \frac{16V^2}{9}$), the monopolist chooses to bundle if:

$$\max_{d} \quad \pi_B - \pi_{NB} = k\left[(1+\alpha)V - 2\sqrt{\frac{2k}{5}} - V + \sqrt{\frac{k}{4}}\right] > 0. \tag{2–10}$$

The relationship between the quantity restraint and the additivity of consumers utility is depicted in Figure 2-6. The shaded region is comprised of all combinations of α and $\hat{k}$ that maintain the incentive to bundle. Unlike the case of capacity constraints that bind unbundled components independently described above, there are some values for the capacity constraint that intensify the incentive to bundle, relative to the unconstrained equilibrium. Capacity constraints that apply to the sum of unbundled components can make bundling more likely. Additionally, tightening the constraint intensifies the incentive to bundle.

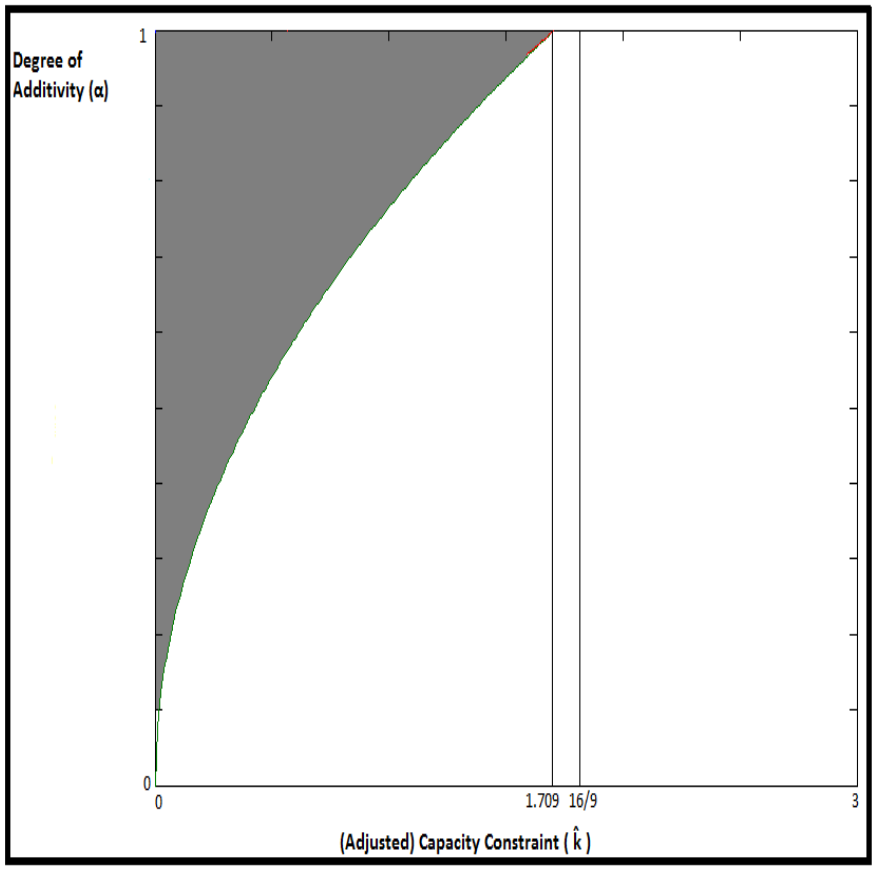

Figure 2-6. Capacity Constraints Imposed On Unbundled Components Jointly

Figure 2-7 compares the two types of quantity restrictions and their effects on the incentive to bundle. It overlays Figures 2-5 and 2-6. It is clear that the incentive to bundle is always stronger with constraints that apply to unbundled components jointly. This result is intuitive; the monopolist is not able to avoid the constraint by splitting the bundle in this case.

Capacity constraints always weaken the incentive to bundle when they only bind on the (higher) bundled quantity. That is, when a quantity restriction that only affects the bundle is tightened, maintaining the incentive to bundle requires a higher value of α. As the constrained capacity falls to the point that it affects the unbundled components, however, tightening the quantity restriction does not always reduce the incentive to

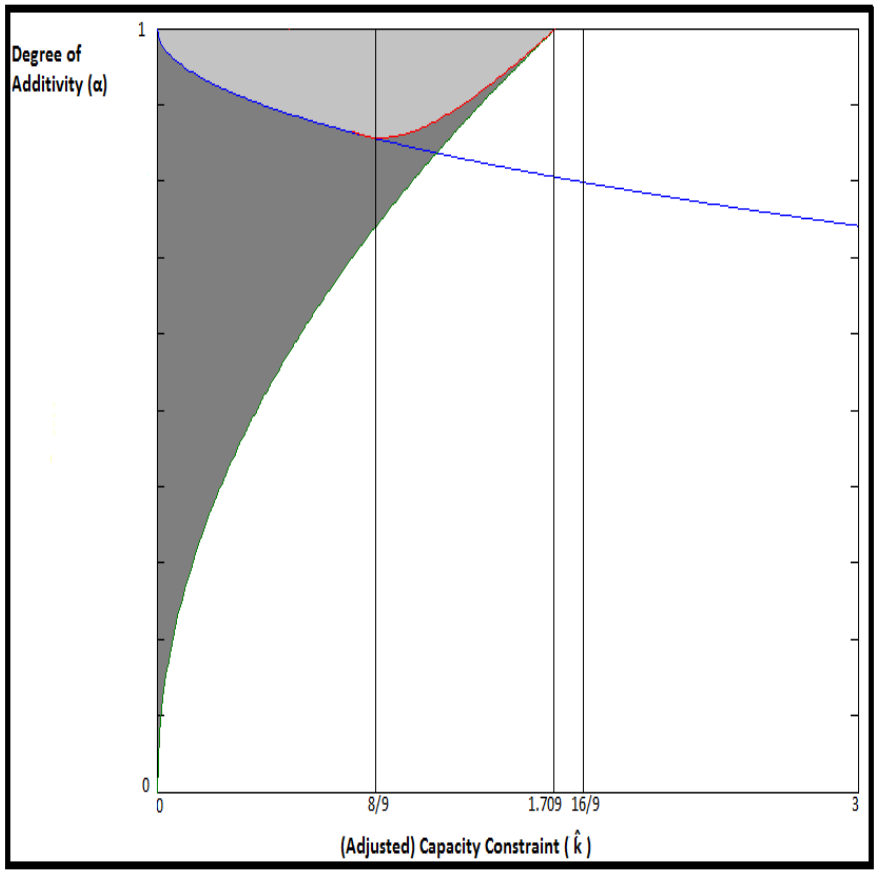

Figure 2-7. Capacity Constraints Compared

bundle. If the restraint applies to unbundled components jointly, tightening a binding constraint increases the incentive to bundle.

2.5 Conclusion

The preceding sections have examined the incentive to bundle events — focusing on the specific case of music concerts — and identified an optimal bundle. The extant literature focuses primarily on factors affecting the incentive to bundle components, but fails to characterize an optimal bundle adequately. Music concerts (and more generally, admission-based events) often present the interesting question of what acts should be bundled. Additionally, the literature places much of its attention on mixed bundles, but this practice is not widely observed. Concert tickets are typically sold as a bundle or separately.

This paper addresses what products a monopolist would choose to bundle. Previous attempts (in the marketing literature) are incapable of simultaneously investigating differentiated products and maintaining a characterizable relationship between those products. That is, they describe how product attributes should differ, but they do not describe the degree of complementarity or substitutability between the product variants. Componets, in this paper, are horizontally differentiated, and optimal bundles are characterized by the degree of differentiation between the component events. This setting alows for the identification of factors that affect both incentive to bundle and the composition of the optimal bundle (e.g., the additivity of consumers' preferences and capacity constraints).

This paper shows that both the incentive to bundle and the determination of the optimal bundle depend upon the level of additivity of consumers utilities. When the monopolist cannot select the degree of differentiation between the component events (i.e., it cannot construct an optimal bundle), it chooses to offer very similar and very different components separately, but bundles moderately differentiated products. The monopolist bundles differentiated products to increase the demand for its bundle, but it also wants to limit the disutility that consumers suffer from attending an act that is substantially different from their indivdual tastes. Increasing the level of additivity exhibited by consumers preferences typically increases the incentive to bundle, and results in a more differentiated optimal bundle. Capacity constraints also affect the incentive to bundle and the composition of the optimal bundle. Whether a capacity constraint reduces or intensifies the incentive to bundle depands on whether the constraint applies to unbundled components separately or jointly. If the constraint applies separately, the incentive to bundle is reduced, because the monopolist can offer the components separately and expand output. If the constriant applies jointly, the incentive to bundle is intensified.

Lastly, the paper demonstrates that duopolists may choose to offer less differentiated products than a monopolist that chooses to bundle. The duopolists differentiate their events enoung to separate the markets — in the single firm setting, this level of differentiation corresponds to the critical level at which multi-purchasing is avoided. The monopolist, however, wishes to increase differentiation between bundled components above this level in order to extract additional surplus.

CHAPTER 3
HOSPITAL MERGERS AND PRODUCT DIFFERENTIATION: AN ECONOMIC APPROACH

3.1 Introduction

The healthcare industry has experienced considerable consolidation since the mid-1990s, leading to greater market concentration. Merger activity slowed between 2002 and 2009 (with approximately sixty mergers announced annually), but has been on the rise since. Seventy-two and ninety mergers were announced in 2010 and 2011, respectively. Market analysts forecast that healthcare mergers will become more common as the Patient Protection and Affordable Care Act is implemented. The new healthcare law creates stronger incentives for hospitals to merge. The current framework for evaluating mergers, laid out in the Federal Trade Commissions 2010 Horizontal Merger Guidelines, does not adequately address the particularities of the healthcare market. In particular, it does not assess the effects of combinations on non-price (e.g., quality) competition in the presence of substantial price regulation.

All merging firms in concentrated industries must notify the Federal Trade Commission (FTC), which undertakes a preliminary merger screening and determines whether to challenge the merger in federal court. Proposed healthcare mergers are notified through the same merger screening program as in other industries and are subject to the review process outlined in the 2010 Horizontal Merger Guidelines. If a merger is expected to result in substantially reduced competition that is likely to harm consumers through higher prices, the FTC seeks a preliminary injunction and may ultimately challenge the merger through a “trial on the merits.” [1]

[1] Once the FTC is awarded a preliminary injunction, merging parties typically abandon the proposed merger. Thus, if the FTC is awarded the preliminary injunction, the merger is effectively blocked.

The 2010 Horizontal Merger Guidelines outline the extensive analysis that is conducted during the FTCs merger screening process and provides information regarding what mergers are likely to be challenged. The analysis that is laid out in the guidelines is intended to determine whether a proposed merger is likely to increase market concentration and result in higher prices paid by consumers. Coate and Ulrick (2006) demonstrate that the number of significant competitors and the increase in the Hirschman Herfindahl Index (HHI) are strong predictors of whether a proposed merger is likely to be challenged by the FTC. The guidelines and analyses of merger enforcement of the FTC, however, are relatively quiet regarding the likely non-price effects of a consummated merger; almost all attention is paid to whether a merger is expected to increase prices through either unilateral or coordinated effects. This approach does not address whether a proposed merger is likely to reduce service quality, which is a particularly important question in price-regulated markets.

This paper focuses on healthcare markets in which prices are set by a regulator or government agency. This focus is adopted for two reasons. First, a number of healthcare markets are either price-regulated or effectively price-regulated. In the United States, healthcare providers that service large numbers of elderly or low-income patients are price-regulated through the Medicare and Medicaid programs. The dimension on which firms compete in these markets is service quality, and it is worthwhile to examine the unique effects of mergers in these markets. Another justification for this approach is the desire to examine quality effects in isolation. Removing price-based strategic behavior, a merger may be examined only for its effect on strategic effects related to quality.

As healthcare mergers become more common, and the FTC is faced with the decision of whether to challenge or accept increased market consolidation, it is important that practitioners are informed of the likely effects of horizontal mergers in the healthcare service industry. This paper examines the likely effect of mergers on

service quality when competitors are price-regulated. The remainder of this paper is organized as follows. Section 2 describes the extensive literature addressing the effect of competition and market consolidation on quality in healthcare markets. Section 3 presents a simple model of mergers in markets characterized by vertical and horizontal product differentiation. The model is employed to predict post-merger quality adjustments in the presence of price regulation. Section 4 provides concluding remarks.

3.2 Healthcare Combinations and Service Quality

Healthcare markets are differentiated products markets. From waiting times to specializations, from the ratio of nurse practitioners to doctors, no two healthcare providers are the same. Consumers choose their provider based, in part, on the product attributes of the available choices. [2] The attributes they consider are both horizontal and vertical. Horizontal attributes include specializations and geographical proximity to the patient. Vertical attributes include quality of facilities, doctor-to-patient ratios, and waiting times. Both types of differentiation affect consumers welfare. As a consequence it is important to characterize the effect of market consolidation on service quality and variety. This section highlights some of the important findings in this area, examining both empirical and theoretical work.

Competition and regulation affect the degree of differentiation in both the horizontal and vertical dimensions. The focus of existing empirical analyses focuses on the vertical dimension and provides mixed results regarding the effect of market concentration on quality. Kessler and McClellan (2000), Ho and Hamilton (2000), Sari (2002), Tay (2003), and Kessler and Geppert (2005) find that increasing market concentration reduces

[2] The set of available providers is, in practice, often determined by the insurance company with which the consumer has coverage. The analysis presented here, however, is only concerned with the strategic behavior driven by consumers choices.

quality, while Mukamel et. al. (2001), and Volpp et. al. (2005) identify the opposite effect. This large body of existing literature concerning the effect of healthcare mergers on service quality identifies inconclusive results. Moreover, there is little empirical research regarding the effect of healthcare mergers on the variety of service and specializations.

The extant theoretical literature treats healthcare markets as spatially differentiated products markets and investigates the effect of adding additional competitors on service quality and variety. Brekke et. al. (2008) examine the effect of adding additional competitors on waiting times and find that reducing travel costs increases waiting times, and that higher hospital density reduces waiting times. The second result is more applicable to an analysis of mergers. Brekke et. al. (2011) examine the effect of adding additional competitors on service quality and find that the effect of competition on service quality is ambiguous. As the authors point out, service quality is similar to (the inverse of) waiting times, but their later work treats quality improvements as costly investments, whereas they had previously treated waiting time reductions as costless. Both analyses assume that healthcare providers are price regulated. The authors do not examine the effect of market concentration on horizontal differentiation.

The analyses conducted by Brekke et. al. are limited by their omission of prices.[3] Additionally, they do not directly address the effect of mergers on product quality; they simply examine whether adding an additional competitor enhances or reduces service quality. The two questions are particularly different in a spatial setting. Mergers do not eliminate competitors in this setting; they simply hand control of one competitor over to another. Norman and Pepal (2000)l directly address the impact of mergers, but their analysis assumes homogenous service quality across competitors. They only investigate the effect of mergers on product variety, finding that mergers increase variety.

[3] While I do not consider price-setting by the individual hospitals, I examine the differential effects between standardized and individualized regulated-price settings.

Empirical analyses identify conflicting evidence regarding the effect of mergers on service quality. They do not address the effect of mergers on product variety. Theoretical analyses are limited. No existing paper, to my knowledge, examines the effect of mergers on both vertical and horizontal differentiation in settings characterized by substantial price regulation.

3.3 Theoretical Model of Vertical and Horizontal Differentiation

This section develops a model of quality competition among horizontally and vertically differentiated healthcare service providers in the presence of regulated prices. A regulator announces prices; observing these prices, each provider chooses its own level of service quality. The analysis considers the unique cases of a single, standardized regulated price that is applied to all firms and individualized regulated prices. These two cases are compared. The section proceeds by identifying the effects of a merger in each of these settings.

Patients are concerned with both the horizontally and vertically differentiated attributes of different service providers and differ only in their horizontal preferences. Patients are uniformly distributed (in horizontal preference or geographic space) along the interval $[0, 1]$.[4] Each patient chooses to purchase one unit of service from the provider whose service offers the highest level of net utility. A patient with horizontal preference θ_i that obtains service from a healthcare facility with specialization l_j and quality q_j receives utility:

$$U(p_j, q_j, \theta_i, l_j) = V + q_j - t|\theta_i - l_j|^2 - p_j, \tag{3–1}$$

where p_j is the price charged by service provider j. The parameter t measures the disutility of visiting a service provider whose horizontal service attribute is not the

[4] Horizontal locations can be interpreted as capturing tastes or physical geographic locations.

"ideal" attribute preferred by the patient. This model assumes that the disutility that patients suffer from visiting a non-ideal location (i.e., travel costs) are convex in the distance traveled. This assumption is realistic in healthcare markets, in which both the costs of traveling in emergency situations and the costs of visiting a provider with a different specialty are likely increasing at an increasing rate in the "distance" traveled. Additionally, this assumption guarantees equilibrium existence if the fixed locations assumption of the stylized model were relaxed.

Three service providers are located along the Hotelling line, with locations l_1, l_2, and l_3, where $l_1 < l_2 < l_3$.[5] The service providers, $j = 1, 2, 3$, independently select their respective levels of service quality, q_j, and sell their service to consumers at their regulated price, p_j. Service providers do not differ in their marginal costs of providing service; without loss of generality, production costs are assumed to be zero. They do, however, incur costs of quality improvements. The convex cost of selecting a quality level q_j is given as $C(q_j) = \frac{q_j^2}{2}$. Accordingly, each provider j maximizes profits:

$$\max_{q_j} \quad \pi_j = p_j D_j(\mathbf{p}, \mathbf{q}) - \frac{q_j^2}{2}, \tag{3–2}$$

where $\mathbf{p}$ and $\mathbf{q}$ are price and quantity vectors, respectively. Each provider j's demand, $D_j(\mathbf{p}, \mathbf{q})$, is increasing in its own quality level and decreasing in the quality level of its most proximate competitor.

Figure 3-1 provides a graphical representation of the market shares. θ_1 denotes the location of the patient whom is indifferent between receiving service from the provider located at l_1 and the one located at l_2. Similarly, θ_2 denotes the location of the patient whom is indifferent between receiving service from the provider located at l_2 and the one

[5] Throughout, the service provider located at l_1 is referred to as Hospital 1, the one located at l_2 is referred to as Hospital 2, and the one located at l_3 is referred to as Hospital 3.

located at l_3. Demand at each location is given as:

$$
\begin{aligned}
D_1(\mathbf{p}, \mathbf{q}) &= \theta_1(p_1, p_2, q_1, q_2) \\
D_2(\mathbf{p}, \mathbf{q}) &= \theta_2(p_2, p_3, q_2, q_3) - \theta_1(p_1, p_2, q_1, q_2) \\
D_3(\mathbf{p}, \mathbf{q}) &= 1 - \theta_2(p_2, p_3, q_2, q_3)
\end{aligned}
\tag{3–3}
$$

It is easy, yet nontrivial, to show that the demand for a particular provider‘s service is directly affect only by its own price and quality and the price an quality of its more proximate competitors.

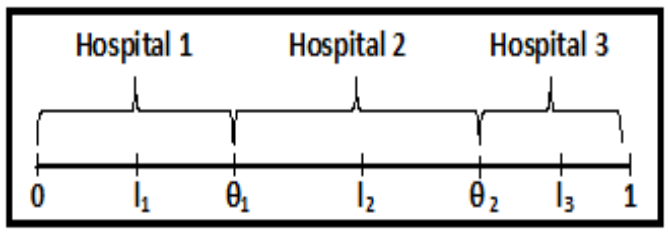

Figure 3-1. Patient Choice

Anticipating the profit-maximizing quality choices of the three independent service providers, a regulator sets service prices. The regulator sets prices to maximize total surplus, subject to service providers selecting their service qualities independently.

$$
\begin{aligned}
\max_{p_1, p_2, p_3} \quad & \int_0^{\theta_1} U(p_1, q_1) + p_1 dx + \int_{\theta_1}^{\theta_2} U(p_2, q_2) + p_2 dx + \int_{\theta_2}^{1} U(p_3, q_3) + p_3 dx - \sum_{q_j=1}^{3} \frac{q_j^2}{2} \\
\text{subject to} \quad & \frac{\partial \pi_j}{\partial q_j} = 0, j = 1, 2, 3.
\end{aligned}
\tag{3–4}
$$

This formulation of the regulators optimization problem specifies a particular sequence of moves and identifies a Subgame Perfect Nash Equilibrium within that sequential interaction. The timing is explicitly given as: Stage 1) The regulator sets the regulated prices, Stage 2) Each service provider selects its own level of quality, independently, Stage 3) Consumers purchase one unit of service from the provider whose service offers the greatest net utility.

The analysis presented in this section considers both standardized regulated prices that apply to all providers and individualized prices. When prices are standardized, the regulator sets a single price, adopting the additional constraint $p_1 = p_2 = p_3$ to the objective function presented above. These two unique settings are compared and discussed. The section then analyzes the effect of a merger between proximate competitors in each setting.

Standardized Prices: Each provider balances the cost of quality improvements against the enhanced market share associated with those improvements. When the three service providers independently set their quality levels (i.e., before any merger takes place), the benefit of quality improvements are driven by own-price effects. The regulated price of a particular service provider determines the marginal revenue of increasing market share through quality adjustments. The pre-merger best reply functions are given as:

$$\begin{aligned} q_1 * (p_1, p_2, p_3, q_2, q_3) &= \frac{p_1}{2t(l_2 - l_1)} \\ q_2 * (p_1, p_2, p_3, q_1, q_3) &= \frac{p_2}{t(l_2 - l_1)} \\ q_3 * (p_1, p_2, p_3, q_1, q_2) &= \frac{p_3}{2t(l_2 - l_1)}, \end{aligned} \tag{3–5}$$

where $p_1 = p_2 = p_3$. When the regulator adopts a standardized regulated price. These best reply functions imply that service providers do not engage in Stage 3 strategic behavior. That is, each hospital makes its quality choice independent of the quality choices of the other two hospitals.

These best reply functions (and the remained of this paper) assume that, due to symmetry between Hospital 1 and Hospital 3, each is located equidistant from Hospital 2. That is, $l_2 - l_1 = l_3 - l_2$. Moreover, due to symmetric interactions with Hospital 1 and Hospital 3, the location of Hospital 2 must be $l_2 = \frac{1}{2}$. Despite locations being exogenously determined in this model, symmetry of the locations of Hospital 1 and

Hospital 3 would arise with endogenous location choices, providing generalizability of the results obtained.[6]

Observing the exogenously determined (symmetric) locations of the three service providers and anticipating the best reply function of each firm, the regulator sets prices to maximize welfare, defined as the sum of consumer and producer surplus. When the regulator is constrained by a requirement that $p_1 = p_2 = p_3$, the Subgame Perfect Nash Equilibrium price is characterized by the following condition:

$$\frac{\partial W}{\partial p} = \int_0^{\theta_1} \frac{\partial q_1}{\partial p} dx + \int_{\theta_1}^{\theta_2} \frac{\partial q_2}{\partial p} dx + \int_{\theta_2}^{1} \frac{\partial q_3}{\partial p} dx - \sum_{j=1}^{3} q_j \frac{\partial q_j}{\partial p} = 0. \tag{3–6}$$

Employing the best reply functions identified above, I am able to identify the standardized regulated price as $p = \frac{2(l_2-l_1)^2 t^2}{6(l_2-l_1)t-1}$.

Pre-Merger Result 1: The regulator chooses a standardized price, $p = \frac{2(l_2-l_1)^2 t^2}{6(l_2-l_1)t-1}$ in Stage 1, and the service providers independently select qualities, $(\mathbf{q}) \equiv (q_1, q_2, q_3) = \left(\frac{(l_2-l_1)t}{6(l_2-l_1)t-1}, \frac{2(l_2-l_1)t}{6(l_2-l_1)t-1}, \frac{(l_2-l_1)t}{6(l_2-l_1)t-1}\right)$ in Stage 2. This results in equilibrium market shares, $(\mathbf{s}) \equiv (s_1, s_2, s_3) = \left(\frac{l_2+l_1}{2} - \frac{1}{6(l_2-l_1)t-1}, \frac{l_3-l_1}{2} + \frac{2}{6(l_2-l_1)t-1}, \frac{2-l_2-l_3}{2} - \frac{1}{6(l_2-l_1)t-1}\right)$

In equilibrium, all providers charge the same price, as imposed here, but service quality is heterogeneous across providers. Hospital 2 offers twice the service quality of its competitors. This result is driven by a full coverage assumption. Hospital 2 has marginal consumers on both sides, whereas its competitors only have marginal consumers to one side. Thus, Hospital 2 experiences twice the marginal revenue of quality adjustments of its competitors.

The regulator's equilibrium price is increasing (decreasing) in both the distance between Hospital 1 and Hospital 2 and the transport cost paramter t whenever the distance between Hospital 1 and Hospital 2 is greater (less) than $\frac{1}{3}$. Increasing the

[6] As mentioned above, the convexity of consumers' travel costs would ensure equilibrium existence in an endogenous-locations setting.

distance between competitors‘ locations or consumers‘ travle costs can be interpreted as softening competition. Thus, when competition is sufficiently weak, increasing it leads to a lower regulated price; when competition is sufficiently strong, increasing it leads to a higher regulated price. The equilibrium levels of service quality are always increasing in the degree of competition.

Individualized Prices: Regulators may not be constrained by a mandate to charge identical prices to all service providers. They may set unique, individualized prices for each provider. When the regulator has the ability to set heterogeneous prices, the constraint, p_1, p_2, p_3, is removed from its optimization problem, implying that social welfare must (weakly) increase above the level enjoyed when prices are homogenous.

The Stage 3 best reply functions that characterize the Subgame Perfect Nash Equilibrium quality choices are similar to those presented in the standardized-price setting. They only differ in one regard: Changing the price charged by one competitor only affects its own quality choice.

By symmetry, I only need to derive the equilibrium prices at Hospital 1 and Hospital 2. The regulator‘s optimal prices are characterized by the following conditions:

Pre-Merger Result 2: The regulator chooses a individualized prices, $(\mathbf{p}) \equiv (p_1, p_2, p_3) = \left(\frac{(l_2-l_1)(l_2+l_1)t}{(l_2-l_1)t+1}, \frac{(l_2-l_1)(l_2+l_1)t}{2[(l_2-l_1)t+1]}, \frac{(l_2-l_1)(l_2+l_1)t}{(l_2-l_1)t+1}\right)$ in Stage 1, and the service providers independently select qualities, $(\mathbf{q}) \equiv (q_1, q_2, q_3) = \left(\frac{(l_2+l_1)}{2[(l_2-l_1)t+1]}, \frac{(l_2+l_1)}{2[(l_2-l_1)t+1]}, \frac{(l_2+l_1)}{2[(l_2-l_1)t+1]}\right)$ in Stage 2. This results in equilibrium market shares, $(\mathbf{s}) \equiv (s_1, s_2, s_3) =$

$$\left(\frac{l_2+l_1}{2} - \frac{1}{4[(l_2-l_1)t+1]}, \frac{l_3-l_1}{2} + \frac{1}{2[(l_2-l_1)t+1]}, \frac{2-l_2-l_3}{2} - \frac{1}{4[(l_2-l_1)t+1]}\right)$$

The equlibrium market shares are likely to be greater for the outside competitors and less for the inside competitor in the presense of individualized, regulated prices. If the degree of horizontal competition, as captured by the locations of the competitors, is sufficiently weak (i.e., $l_1 < \frac{1}{6}$), this result is unambiguous. If the horizontal locations are not sufficiently far apart, however, obtaining an alternative result requires that $t > \frac{l_1+4.5}{4l_1-6l_1^2-0.5}$. The minimum value of t that can satisfy this condition is 28.9. This feature

is particularly interesting,as greater values of l_1 and lower values of t imply different forms of heightened competition. They, however, have unique effects on the relationship between equiliubrium market shares under stnadardized and individualized, regulated prices.

Proposition 3.1. *If $l_1 < \frac{1}{6}$, the equilibrium market shares under individualized, regulated prices are greater (less) for Hospital 1 and Hospital 3 (Hospital 2). If $l_1 > \frac{1}{6}$, the equilibrium market shares are greater (less) for Hospital 1 and Hospital 3 (Hospital 2) for all values of $t < 28.9$.*

The regulator anticipates the heightened marginal revenue of quality improvements of Hospital 2, and sets prices to equalize quality across providers. Given the convex costs of quality improvements, equalizing service quality across competitors maximizes social welfare. Consequently, the price at Hospital 2 is half the price at Hospitals 1 and 3; patients at Hospital 2 enjoy greater surplus than those that purchase service from "outside providers.

The remainder of this chapter analyzes the effects of a merger on regulated prices and unregulated service quality. It compares the post-merger environment to the pre-merger environment described above. Only mergers between most-proximate competitors are considered, as mergers between non-neighboring competitors do not have any effect on quality choices in the presence of regulated prices. When prices are regulated, regardless of whether they are homogenous, mergers between non-neighboring competitors have no effect.

Proposition 3.2. *In the presence of regulated pricing, mergers between non-neighboring competitors have no effect of equilibrium quality provision or prices.*

Post-Merger Standardized Prices: As mergers between non-neighboring competitors have no effect, and the two outside firms are assumed to be identical (ex ante), it is only relevant to consider a merger between Hospital 1 and Hospital 2. Such a merger would alter the maximization problem of the newly combined entity and alter incentives for

quality adjustments. The newly combined provider maximizes profits:

$$\max_{q_1,q_2} \quad \pi = p_1 D_1(\mathbf{p},\mathbf{q}) + p_2 D_2(\mathbf{p},\mathbf{q}) - \frac{q_1^2}{2} - -\frac{q_2^2}{2}. \tag{3–7}$$

Solving the merged providers maximization problem identifies altered incentives for quality provision. As discussed above, in the presence of regulated prices, providers make their quality decisions based on their ability to attract marginal consumers. The merged providers incentive regarding marginal consumers between Hospital 1 and Hospital 2 are weakened, as any switching only affects the price received, not actual market share. When prices are equalized this affect disappears.

Post-Merger Result 1: The regulator chooses a standardized price, $p = \frac{4(l_2-l_1)^2t^2}{6(l_2-l_1)t-1}$ in Stage 1, and the service providers independently select qualities, $(\mathbf{q}) \equiv (q_1, q_2, q_3) = \left(0, \frac{2(l_2-l_1)t}{6(l_2-l_1)t-1}, \frac{2(l_2-l_1)t}{6(l_2-l_1)t-1}\right)$ in Stage 2.

When standardized pricing is adopted by — or imposed upon — the regulator, there is no incentive to provide quality at Hospital 1. Additionally, the marginal revenue associated with quality provision is identical at Hospital 2 and Hospital 3, as each is only concerned with one group of marginal consumers.

Comparing the pre-merger and post-merger provision of quality in a price-regulated market with standardized pricing, it can be seen that the merger places substantial upward pressure on prices and has differential effects on quality at the three service providers. First, despite the presence of a price-setting regulator that seeks to maximize welfare, the merger still results in upward pressure on prices. The regulator doubles the price after the combination. Additionally, the merger has effects on quality provision. Service quality at Hospital 1 falls to zero, at Hospital 2 remains constant, and at Hospital 3 doubles.

Post-Merger Individualized Prices: As with the pre-merger environment, it is important to consider the effect of removing the homogenous prices mandate on the regulator. As before, removing the constraint, $p_1 = p_2 = p_3$, (weakly) improves total

surplus.[7] . The mergers effect on regulated prices and quality readjustments is less straightforward.

In Stage 1, the regulator sets prices to maximize welfare, anticipating second-stage behavior by the firms. The merger affects the Stage 2 best reply functions of the merging hospitals, as quality competition between them is reduced by the merger. It does not, however, affect the best reply of the non-merging hospital or the optimal price of its service. Here, I examine the effect of the merger on equilibrium regulated prices at the merging hospitals. Holding prices at their pre-merger levels, the marginal welfare effect of increasing the prices at Hospital 1 and Hospital 2 can be identified as:

$$\frac{\partial W}{\partial p_1} = \int_{\theta_1}^{\theta_2} \frac{\partial q_2}{\partial p_1} dx + [p_1 - p_2] \left[\frac{\partial \theta_1}{\partial q_2} \frac{\partial q_2}{\partial p_1} \right] + [p_2 - p_3] \left[\frac{\partial \theta_2}{\partial q_2} \frac{\partial q_2}{\partial p_1} \right], \textit{and} \tag{3–8}$$

$$\frac{\partial W}{\partial p_2} = \int_{0}^{\theta_1} \frac{\partial q_1}{\partial p_2} dx + [p_1 - p_2] \left[\frac{\partial \theta_1}{\partial q_1} \frac{\partial q_1}{\partial p_2} \right]. \tag{3–9}$$

It is simple to observe that the merger's effect on the optimal regulated price at Hospital 2 is negative; the regulator will reduce the price at Hospital 2 after the transaction. The merger's effect on the price at Hospital 1 is, however, ambiguous. While the first term of $\frac{\partial W}{\partial p_1}$,as evaluated at the pre-merger prices, is negative, the second two terms are positive. Balancing these effects requires precise specification of the horizontal locations and the transport cost parameter t.

Post-Merger Result 2: The merger has an ambiguous effect on the regulated price at Hospital 1, a negative effect on the regulated price at Hospital 2, and no effect on the regulated price at Hospital 3. Without assigning numerical values to the exogenous parameters of the model, the effect of the merger on service qualities is ambiguous.

[7] In the pre-merger environment, prices changed when this constraint was removed, implying that welfare strictly improved

3.4 Conclusion

The Federal Trade Commission reviews hospital mergers and chooses to block mergers that are likely to “restrict competition.” The analysis that the FTC conducts is laid out in the 2010 Horizontal Merger Guidelines. These guidelines focus on the likely effect of a proposed merger on prices; mergers that are expected to increase prices through the elimination of a viable competitor are often blocked. The guidelines mention product differentiation as a factor that softens competition and makes post-merger price increases less likely. They do not, however, address the likely effects of a transaction on post-merger product differentiation, which is a substantial determinant of patients welfare. The analysis presented in this paper is intended to inform practitioners in this area.

This paper examines the effect of mergers on service quality in price-regulated markets. I adopt a three-stage game, in which timing is as follows: State 1) The regulator sets the regulated prices, Stage 2) Each service provider selects its own level of quality, indepently, Stage 3) Consumers purchase one unit of service from the provider whose service offers the greatest net utility. In this setting, the effect of a merger between neighboring competitors depends on the nature of price regulation. When regulated prices must be equal across all providers, the merger results in higher prices at all service providers, but it has differential effects on service quality. The quality at one of the merging providers falls, and at the other, remains constant. Interestingly, the service quality at the non-merging provider increases. When regulated prices may vary across providers, the effect of the merger is ambiguous. The regulated price and service quality at the non-merging provider remain constant. The regulated prices however may increase or decrease, leading to ambiguous effects on quality choices in Stage 2.

When a regulator may choose to set standardized or individualized prices, it is always (weakly) welfare enhancing to select the latter. Standardized prices impose an

additional constraint on the regulators welfare optimization problem, and thus, cannot enhance welfare.

APPENDIX: MATHEMATICAL DERIVATIONS

Corollary 1(i): *When $\hat{e_B} > e_G$, and the entrant is able to profitably enter, any increase in the marginal cost of greenwash reduces the amount of greenwash undertaken by the incumbent at a decreasing rate.*

The First Order Condition (FOC) for the profit-maximizing level of reported harm is given by:

$$\frac{V^2(4\hat{e_B}-7e_G)}{(4\hat{e_B}-e_G)^3} = k(e-\hat{e_B}).$$

Totally differentiating the FOC w.r.t. the marginal cost of greenwashing provides:

$$\frac{V^2(80e_G-32\hat{e_B})}{(4\hat{e_B}-e_G)^4}\frac{\partial\hat{e_B}}{\partial k} = (e-\hat{e_B}) - k\frac{\partial\hat{e_B}}{\partial k}.$$

As $k > \frac{\partial^2 TR}{\partial\hat{e_B}^2}$ in order to satisfy the Second Order Sondition (SOC), $\frac{\partial\hat{e_B}}{\partial k} > 0$. Taking the second order total derivative of the FOC allows us to verify the concavity of the optimal $\hat{e_B}(k)$ function. A general representation of the first total derivative is given as:

$$-\frac{\partial^2 TR}{\partial\hat{e_B}^2}\left(\frac{\partial\hat{e_B}}{\partial k}\right)^2 = (e_B-\hat{e_B}) - k\frac{\partial\hat{e_B}}{\partial k}.$$

Thus, the second total derivative w.r.t. k is:

$$-\frac{\partial^3 TR}{\partial\hat{e_B}^3}\left(\frac{\partial\hat{e_B}}{\partial k}\right)^2 - \frac{\partial^2 TR}{\partial\hat{e_B}^2}\frac{\partial^2\hat{e_B}}{\partial k^2} = -2\frac{\partial\hat{e_B}}{\partial k} - k\frac{\partial^2\hat{e_B}}{\partial k^2}.$$

$$\left(k-\frac{\partial^2 TR}{\partial\hat{e_B}^2}\right)\frac{\partial^2\hat{e_B}}{\partial k^2} = \frac{\partial^3 TR}{\partial\hat{e_B}^3}\left(\frac{\partial\hat{e_B}}{\partial k}\right)^2 - 2\frac{\partial\hat{e_B}}{\partial k}.$$

Thus, we observe that $\frac{\partial^2\hat{e_B}}{\partial k^2} < 0$. As a consequence, within Case 1, increases in the marginal cost of greenwashing increase the incumbent's profit-maximizing report at a decreasing rate.

Corollary 1(ii): *When $\hat{e_B} > e_G$, and the entrant is able to profitably enter, any increase in the reported level of environmental harm by the incumbent decreases aggregate environmental harm at a decreasing rate. That is, greenwash by the incumbent increases aggregate harm at an increasing rate. Additionally, increases in the incumbent's marginal cost of greenwashing reduce aggregate harm at a decreasing rate.*

Taking the first order partial derivative of the aggrehate environmental harm in Case 1, I obtain:

$$\frac{\partial H}{\partial \hat{e_B}} = \frac{-2V(2e_B+e_B)}{(4\hat{e_B}-e_G)^2} < 0.$$

Taking the second order partial derivative of the aggrehate environmental harm in Case 1, I obtain:

$$\frac{\partial^2 H}{\partial \hat{e_B}^2} = \frac{16V(2e_B+e_B)}{(4\hat{e_B}-e_G)^3} > 0.$$

Within Case 1, increases in the incumbent's report decrease harm at a decreasing rate, or alternatively, increases in the profit-maximizing level of greenwash increase aggregate environmental harm at an increasing rate.

A generalized expression for aggregate environmental as a function of the marginal cost of greenwashing is given as, $H = H(\hat{e_B}(k))$. Differentiating this expression gives:

$$\frac{\partial H}{\partial k} = \frac{\partial H}{\partial \hat{e_B}} \frac{\partial \hat{e_B}}{\partial k}.$$

As $\frac{\partial H}{\partial \hat{e_B}} < 0$, and $\frac{\partial \hat{e_B}}{\partial k} > 0$, we observe that $\frac{\partial H}{\partial k} < 0$. Taking the second derivative of the general expression for harm gives:

$$\frac{\partial^2 H}{\partial k^2} = \frac{\partial H}{\partial \hat{e_B}} \frac{\partial^2 \hat{e_B}}{\partial k^2} + \frac{\partial^2 H}{\partial \hat{e_B}^2} \frac{\partial \hat{e_B}}{\partial k} > 0.$$

Thus, within Case 1, increases in the incumbent's marginal cost of greenwash decrease harm at a decreasing rate.

Corollary 1(iii): *When $\hat{e_B} > e_G$, and the entrant is able to profitably enter, the reported level of harm by the incumbent that maximizes consumer surplus is less than e_B, and*

(a) when $\hat{e_B} = \frac{4e_B-3e_G}{16}$ results in entry by the green firm, $\hat{e_B} = \frac{4e_B-3e_G}{16}$ maximizes consumer surplus,

(b) when $\hat{e_B} = \frac{4e_B-3e_G}{16}$ does not result in entry by the green firm, a reported level of harm just above the entry threshold level of harm maximizes consumer surplus.

Defining consumer surplus as $CS \equiv \int_0^{\hat{\theta}} V - \theta e_B - p_B \, d\theta + \int_{\hat{\theta}}^{\tilde{\theta}} V - \theta e_G - p_G \, d\theta$, it follows that:

$$\frac{\partial CS}{\partial \hat{e_B}} = \int_0^{\hat{\theta}} -\frac{\partial p_B}{\partial \hat{e_B}} \, d\theta + (V - \hat{\theta} e_B - p_B) \frac{\partial \hat{\theta}}{\partial \hat{e_B}} + [\hat{e_B} - \hat{e_B}] \frac{\partial \hat{\theta}}{\partial \hat{e_B}} \hat{\theta} + \int_{\hat{\theta}}^{\tilde{\theta}} -\frac{\partial p_G}{\partial \hat{e_B}} \, d\theta + (V - \tilde{\theta} e_G - p_G) \frac{\partial \tilde{\theta}}{\partial \hat{e_B}}$$

-(V- e$_G - p_G)\frac{\partial\hat{\theta}}{\partial\hat{e_B}}$.

As $V - \hat{\theta}\hat{e_B} - p_B = V - \hat{\theta}e_G - p_G$, and $V - \tilde{\theta}e_G - p_G = 0$, the marginal effect of $\hat{e_B}$ on *CS* reduces to:

$$\frac{\partial CS}{\partial\hat{e_B}} = \int_0^{\hat{\theta}} -\frac{\partial p_B}{\partial\hat{e_B}}\, d\theta + [\hat{e_B} - e_B]\frac{\partial\hat{\theta}}{\partial\hat{e_B}}\hat{\theta} + \int_{\hat{\theta}}^{\tilde{\theta}} -\frac{\partial p_G}{\partial\hat{e_B}}\, d\theta$$

$$\frac{\partial CS}{\partial\hat{e_B}} = \frac{V^2(4e_B - 16\hat{e_B} - 3e_G)}{(4\hat{e_B} - e_G)^3}$$

As the second partial is clearly negative, the consumer surplus function (in Case 1) obtains a maximum at $\hat{e_B} = \frac{4e_B - 3e_G}{16}$. It is possible, however, that this maximum is not acheivable (within Case 1) if e_B and e_G are particularly close together of the fixed costs of entry are sufficiently high.

Corollary 2: *If $\hat{e_B} > e_G$, when greenwash is sufficiently strong to foreclose the market to a greener entrant, the incumbent's profits exhibit an upward jump, and the marginal benefit of greenwash exhibits an upward jump. Together, these characteristics imply that the profit-maximizing report jumps down.*

Defining TR_i as the total revenue that the incumbent form receives in Case *i*, it can be shown that total revenue jumps up when grenwash is sufficiently strong to shift the market from Case 1 to Case 2 by deterring entry:

$$TR_1 < TR_2$$

$$\frac{V^2(\hat{e_B} - e_G)}{(4\hat{e_B} - e_G)^2} < \frac{V^2}{4\hat{e_B}}$$

$$4\hat{e_B}(\hat{e_B} - e_G) < (4\hat{e_B} - e_G)^2$$

$$4\hat{e_B}^2 - 4\hat{e_B}e_G < 16\hat{e_B}^2 - 8\hat{e_B}e_G + e_G^2$$

$$12\hat{e_B}^2 - 4\hat{e_B}e_G + e_G^2 > 0.$$

Additionally, it can be shown that the marginal benefit of greenwash is greater once the incumbent is able to secure monopoly status. Defining MB_i as the marginal benefit of greenwash within Case *i*, we observe:

$$MB_1 < MB_2$$

$$\frac{V^2(4\hat{e_B} - 7e_G)}{(4\hat{e_B} - e_G)^3} < \frac{V^2}{4\hat{e_B}^2}$$

$$4\hat{e_B}^2(4\hat{e_B} - 7e_G) < (4\hat{e_B} - e_G)^3$$

$$16\hat{e_B}^3 - 28\hat{e_B}^2 e_G < 64\hat{e_B}^3 - 48\hat{e_B}^2 e_G + 12\hat{e_B} e_G^2 - e_G^2$$
$$-48\hat{e_B}^3 + 20\hat{e_B}^2 e_G - 12\hat{e_B} e_G^2 + e_G^2 < 0$$

Thus, when greenwash is sufficiently strong to deter entry (between Cases 1 and 2), the incumbent's profits jump up, as does the marginal benefit it receives from greenwashing.

Corollary 3(i): *When the entrant is not able to profitably enter, any increase in the marginal cost of greenwash reduces the amount of greenwash undertaken by the incumbent at a decreasing rate.*

The First Order Condition (FOC) for the profit-maximizing level of reported harm is given by:

$$\frac{V^2}{4\hat{e_B}^2} = k(e_B - \hat{e_B}).$$

Totally differentiating the FOC w.r.t. the marginal cost of greenwashing provides:

$$\frac{-V^2}{2\hat{e_B}^3} = (e_B - \hat{e_B}) - k\frac{\partial \hat{e_B}}{\partial k}$$
$$\left(k - \frac{V^2}{2\hat{e_B}^3}\right)\frac{\partial \hat{e_B}}{\partial k} = (e_B - \hat{e_B})$$

As $k > \frac{\partial^2 TR}{\partial \hat{e_B}^2}$ in order to satisfy the Second Order Sondition (SOC), $\frac{\partial \hat{e_B}}{\partial k} > 0$. Taking the second order total derivative of the FOC allows us to verify the concavity of the optimal $\hat{e_B}(k)$ function:

$$\left(1 + \frac{3V^2}{2\hat{e_B}^4}\right)\frac{\partial \hat{e_B}}{\partial k} + \left(k - \frac{V^2}{2\hat{e_B}^3}\right)\frac{\partial^2 \hat{e_B}}{\partial k^2} = -\frac{\partial \hat{e_B}}{\partial k},$$

Thus, we observe that $\frac{\partial^2 \hat{e_B}}{\partial k^2} < 0$. As a consequence, within Cases 2 and 3, increases in the marginal cost of greenwashing increase the incumbent's profit-maximizing report at a decreasing rate.

Corollary 3(ii): *Within the range of marginal costs of greenwash that gives rise to a monopoly market structure, increases in the marginal cost of greenwash decreases aggregate environmental harm at a decreasing rate.*

From the methematical derivation for Corollary 2:

$$\frac{\partial H}{\partial k} = \frac{\partial H}{\partial \hat{e_B}}\frac{\partial \hat{e_B}}{\partial k}.$$

As $\frac{\partial H}{\partial \hat{e_B}} < 0$, and $\frac{\partial \hat{e_B}}{\partial k} > 0$, we observe that $\frac{\partial H}{\partial k} < 0$. Taking the second derivative of the general expression for harm gives:

$$\frac{\partial^2 H}{\partial k^2} = \frac{\partial H}{\partial \hat{e_B}} \frac{\partial^2 \hat{e_B}}{\partial k^2} + \frac{\partial^2 H}{\partial \hat{e_B}^2} \frac{\partial \hat{e_B}}{\partial k} > 0.$$

Thus, within Cases 2 and 3, increases in the incumbent's marginal cost of greenwash decrease harm at a decreasing rate.

Corollary 3(iii): *Consumer surplus jumps down whenever entry is foreclosed, regardless of whether $\hat{e_B} > e_G$. Additionally, within the range of marginal costs of greenwash that gives rise to a monopoly market structure, increases in the marginal cost of greenwash increase consumer surplus at a decreasing rate.*

Defining consumer surplus in the monopoly cases as $CS \equiv \int_0^{\hat{\theta}} V - \theta e_B - p_B \, d\theta$, and defining consumer surplus in Case 4 as $CS \equiv \int_0^{\hat{\theta}} V - \theta e_G - p_G \, d\theta + \int_{\hat{\theta}}^{\tilde{\theta}} V - \theta e_B - p_B \, d\theta$, it is clear that consumer surplus jumps down any time that entry is foreclosed. First, I demonstrate that Consumer surplus jumps down when the market moves from Case 1 to Case 2. Here, I define $\hat{\theta_1}$ and $\tilde{\theta_1}$ as in the Corollary 3 proof and $\hat{\theta_2}$ is the location of the consumer that is indifferent between consuming from a monopolist and abstaining from consumption. $\tilde{\theta_1} > \hat{\theta_2} > \hat{\theta_1}$. For simplicity, the monopoly price is denoted as p_M. The loss to monopoly (between case 1 and Case 2) for a given $\hat{e_B}$ is given as:

$$\int_0^{\hat{\theta_1}} p_M - p_B \, d\theta + \int_{\hat{\theta_1}}^{\hat{\theta_2}} (e_B - e_G)\theta + (p_M - p_G) \, d\theta + \int_{\hat{\theta_2}}^{\tilde{\theta_1}} V - \theta e_G - p_G \, d\theta > 0$$

Consumer surplus jumps down when the market arrangement shifts from that described by Case 1 to that described by Case 2. Next, I demonstrate that Consumer surplus jumps down when the market moves from Case 3 to Case 4. Here, I define $\hat{\theta_4}$ and $\tilde{\theta_4}$ as the location of the consumer that is indifferent between the green "low quality" variant and the incumbent's variant and the location of the consumer that is indifferent between consuming from the incumbent and abstaining from consumption, respectively. Also, $\hat{\theta_3}$ is the location of the consumer that is indifferent between consuming from a monopolist and abstaining from consumption. $\tilde{\theta_4} > \hat{\theta_3} > \hat{\theta_4}$. For simplicity, the monopoly price is denoted as p_M. The loss to monopoly (between case 1 and Case 2) for a given $\hat{e_B}$ is given as:

$$\int_0^{\hat{\theta_4}} (e_B - e_G)\theta + (p_M - p_G) \, d\theta + \int_{\hat{\theta_4}}^{\hat{\theta_3}} p_M - p_B \, d\theta + \int_{\hat{\theta_3}}^{\tilde{\theta_4}} V - \theta e_B - p_B \, d\theta > 0$$

Consumer surplus jumps down when the market arrangement shifts from that described by Case 4 to that described by Case 3. Thus, whenever the market is foreclosed, consumer surplus jumps down. Finally, within the monopoly market, consumer surplus increases at a decreasing rate as $\hat{e_B}$ increases:

$$\frac{\partial CS}{\partial \hat{e_B}} = \frac{V^2(e_B - \hat{e_B})}{4\hat{e_B}^3} > 0$$
$$\frac{\partial^2 CS}{\partial \hat{e_B}^2} = \frac{V^2(2\hat{e_B} - 3e_B)}{4\hat{e_B}^4} < 0$$

Corollary 4(i): *When $\hat{e_B} < e_G$, and the entrant is able to profitably enter, the incumbent's profits exhibit a downward jump, but the marginal benefit of greenwash exhibits an upward jump. Together, these characteristics imply that when the market is not fully covered, any increase in the marginal cost of greenwash reduces the amount of greenwash undertaken by the incumbent at a decreasing rate.*

Defining TR_i as the total revenue that the incumbent form receives in Case *i*, it can be shown that total revenue jumps up when grenwash is sufficiently strong to shift the market from Case 3 to Case 4 by deterring entry:

$$TR_3 > TR_{4a}$$
$$\frac{V^2}{4\hat{e_B}} > \frac{4V^2(e_G - \hat{e_B})e_G}{(4e_G - \hat{e_B})^2\hat{e_B}}$$
$$16e_G^2 - 8\hat{e_B}e_G + \hat{e_B}^2 > 16e_G^2 - 16\hat{e_B}e_G$$
$$8\hat{e_B}e_G + \hat{e_B}^2 > 0$$

Additionally, it can be shown that the marginal benefit of greenwash is greater once theentrant is able to enter. Defining MB_i as the marginal benefit of greenwash within Case *i*, we observe:

$$MB_3 < MB_{4a}$$
$$\frac{V^2}{4\hat{e_B}^2} < \frac{-4V^2e_G(2\hat{e_B}^2 - 3\hat{e_B}e_G + e_4G^2)}{(4e_G - \hat{e_B})^3\hat{e_B}^2}$$
$$4\hat{e_B}^2(4\hat{e_B} - 7e_G) < (4\hat{e_B} - e_G)^3$$
$$32\hat{e_B}^2e_G - 48\hat{e_B}e_G^2 + 64e_G^3 > -\hat{e_B}^3 + 12\hat{e_B}^2e_G - 48\hat{e_B}e_G^2 + 64e_G^3$$
$$20\hat{e_B}^2e_G + \hat{e_B}^3 > 0$$

Thus, when greenwash is sufficiently strong to facilitate entry (between Cases 3 and 4), the incumbent's profits jump down, but the marginal benefit it receives from greenwashing jumps up. We can observe that within Subcase 4a, increases in the marginal cost of greenwash increase the incumbent's profit-maximizing level of reported harm at a decreasing rate. Totally differentiating the incumbent's FOC for profit maximization in Stage 1, I obtain:

$$\frac{-8V^2(6\hat{e_B}^2 e_G - 3\hat{e_B}^3 + 16e_G^3 - 16\hat{e_B}e_G^2)}{(4e_G - \hat{e_B})^4 \hat{e_B}^3}\frac{\partial \hat{e_B}}{\partial k} = (e - \hat{e_B}) - k\frac{\partial \hat{e_B}}{\partial k}.$$

As $k > \frac{\partial^2 TR}{\partial \hat{e_B}^2}$ in order to satisfy the Second Order Sondition (SOC), $\frac{\partial \hat{e_B}}{\partial k} > 0$. Taking the second order total derivative of the FOC allows us to verify the concavity of the optimal $\hat{e_B}(k)$ function. A general representation of the first total derivative is given as:

$$-\frac{\partial^2 TR}{\partial \hat{e_B}^2}\left(\frac{\partial \hat{e_B}}{\partial k}\right)^2 = (e_B - \hat{e_B}) - k\frac{\partial \hat{e_B}}{\partial k}.$$

Thus, the second total derivative w.r.t. k is:

$$-\frac{\partial^3 TR}{\partial \hat{e_B}^3}\left(\frac{\partial \hat{e_B}}{\partial k}\right)^2 - \frac{\partial^2 TR}{\partial \hat{e_B}^2}\frac{\partial^2 \hat{e_B}}{\partial k^2} = -2\frac{\partial \hat{e_B}}{\partial k} - k\frac{\partial^2 \hat{e_B}}{\partial k^2}.$$

$$\left(k - \frac{\partial^2 TR}{\partial \hat{e_B}^2}\right)\frac{\partial^2 \hat{e_B}}{\partial k^2} = \frac{\partial^3 TR}{\partial \hat{e_B}^3}\left(\frac{\partial \hat{e_B}}{\partial k}\right)^2 - 2\frac{\partial \hat{e_B}}{\partial k}.$$

Thus, we observe that $\frac{\partial^2 \hat{e_B}}{\partial k^2} < 0$. As a consequence, within Subcase 4a, increases in the marginal cost of greenwashing increase the incumbent's profit-maximizing report at a decreasing rate.

Corollary 4(ii): *When $\hat{e_B} < e_G$, and the entrant is able to profitably enter, any increase in the marginal cost of greenwash decreases aggregate environmental harm at a decreasing rate. That is, greenwash by the incumbent increases aggregate harm at an increasing rate.*

From the mathematical derivation for Corollary 2:

$$\frac{\partial H}{\partial k} = \frac{\partial H}{\partial \hat{e_B}}\frac{\partial \hat{e_B}}{\partial k}.$$

As $\frac{\partial H}{\partial \hat{e_B}} < 0$, and $\frac{\partial \hat{e_B}}{\partial k} > 0$, we observe that $\frac{\partial H}{\partial k} < 0$. Taking the second derivative of the general expression for harm gives:

$$\frac{\partial^2 H}{\partial k^2} = \frac{\partial H}{\partial \hat{e_B}}\frac{\partial^2 \hat{e_B}}{\partial k^2} + \frac{\partial^2 H}{\partial \hat{e_B}^2}\frac{\partial \hat{e_B}}{\partial k} > 0.$$

Thus, within Subcase 4a, increases in the incumbent's marginal cost of greenwash decrease harm at a decreasing rate.

Corollary 4(iii): *When $\hat{e_B} < e_G$, and the entrant is able to profitably enter, any increase in the marginal cost of greenwash increases consumer surplus. That is, greenwash by the incumbent decreases consumer surplus.*

Defining consumer surplus as $CS \equiv \int_0^{\hat{\theta}} V - \theta e_G - p_G \, d\theta + \int_{\hat{\theta}}^{\tilde{\theta}} V - \theta e_B - p_B \, d\theta$, it follows that:

$\frac{\partial CS}{\partial \hat{e_B}} = \int_0^{\hat{\theta}} -\frac{\partial p_G}{\partial \hat{e_B}} \, d\theta + (V - \hat{\theta} e_G - p_G) \frac{\partial \hat{\theta}}{\partial \hat{e_B}} + \int_{\hat{\theta}}^{\tilde{\theta}} -\frac{\partial p_B}{\partial \hat{e_B}} \, d\theta + (V - \tilde{\theta} e_B - p_B) \frac{\partial \tilde{\theta}}{\partial \hat{e_B}} - (V - \hat{\theta} e_B - p_B) \frac{\partial \hat{\theta}}{\partial \hat{e_B}}$

As $V - \hat{\theta}\hat{e_B} - p_B = V - \hat{\theta} e_G - p_G$, and $V - \tilde{\theta}\hat{e_B} - p_B = 0$, the marginal effect of $\hat{e_B}$ on *CS* reduces to:

$$\frac{\partial CS}{\partial \hat{e_B}} = \int_0^{\hat{\theta}} -\frac{\partial p_G}{\partial \hat{e_B}} \, d\theta + \int_{\hat{\theta}}^{\tilde{\theta}} -\frac{\partial p_B}{\partial \hat{e_B}} \, d\theta + (e_B - \hat{e_B}) \left[\frac{\partial \hat{\theta}}{\partial \hat{e_B}} \hat{\theta} + \frac{\partial \tilde{\theta}}{\partial \hat{e_B}} \tilde{\theta} \right].$$

$$\frac{\partial CS}{\partial \hat{e_B}} = \frac{3V^2 e_G (4e_G + \hat{e_B})}{\hat{e_B}(4e_G - \hat{e_B})^3} + (e_B - \hat{e_B}) \frac{V^2 (2e_G^2 \hat{e_B} - 6e_G \hat{e_B}^2 + 16e_G^3)}{\hat{e_B}^3 (4e_G - \hat{e_B})^3} > 0$$

Any increase in the incumbent's reported level of harm (in Subcase 4a) results leads to improved consumer welfare.

Corollary 5: *When $\hat{e_B} < e_G$, and when the market is fully covered, any increase in the marginal cost of greenwash that reduces the amount of greenwash undertaken by the firm increases consumer surplus at a decreasing rate.*

Defining consumer surplus as $CS \equiv \int_0^{\frac{1}{3}} V - \theta e_G - p_G \, d\theta + \int_{\frac{1}{3}}^{1} V - \theta e_B - p_B \, d\theta$, it follows that:

$$\frac{\partial CS}{\partial \hat{e_B}} = \frac{-1}{3} \frac{\partial p_G}{\partial \hat{e_B}} - \frac{2}{3} \frac{\partial p_B}{\partial \hat{e_B}}$$

$$\frac{\partial CS}{\partial \hat{e_B}} = \frac{-5}{3} \frac{\partial p_G}{\partial \hat{e_B}} = \frac{5}{9} > 0$$

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BIOGRAPHICAL SKETCH

Thomas Knight earned his Bachelor of Arts degree in economics and environmental studies at New College of Florida in 2007. He received his Master of Science degree in economics: competition and regulation from Tilburg University in 2009. In 2009, he entered the doctoral program in economics at the University of Florida, where he specialized in game theory, industrial organization, and experimental economics.

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