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# Social Responsibility and Product Innovation

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This paper examines the incentives of firms to invest in socially responsible product innovations. Our analysis connects the existence of socially responsible innovations to the presence of intrinsic and extrinsic social responsibility preferences. In addition to deriving economic value from the product, consumers have heterogeneous intrinsic needs to consume products that are socially responsible. They also have extrinsic social comparison preferences that are based on their meetings with others in social interactions. The frequency of these meetings are endogenous to the consumption choices of consumers. A consumer enjoys a social comparison benefit if her consumption decision is more socially responsible than the consumer that she meets in a social interaction and a social comparison cost if it is less socially responsible.

The analysis reveals a nonmonotonic effect of social comparison effects on innovation incentives. When the economic value of a product is relatively small, the incentive to innovate decreases as social comparison effects increase. By contrast, when the economic value of a product is sufficiently large, increases in social comparison effects increase the incentive to innovate. Social comparison benefits and costs have different effects on competition between firms. In particular, social comparison benefits soften price competition, whereas social comparison costs tend to exacerbate price competition. We also identify market conditions where a monopoly invests more or less compared to a firm facing competition.

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## 1. Introduction

In 2009, a study of more than 6,000 consumers conducted for the Grocery Manufacturer's Association (GMA) found that sustainability influences the buying decisions of more than half of consumers and 57% of those surveyed would pay more for socially responsible products.[1] In a May 2014 interview, the director of sustainability at Deloitte (and an author of the study) indicated that this percentage has increased since the study was conducted. In the past, a firm like The Body Shop was unique because its positioning was based on developing socially responsible products made from natural ingredients without animal testing. Today it is rare to find a major consumer products firm that is not actively conducting research and development (R&D) to develop socially responsible products. About 90% of Fortune 500 companies report developing socially responsible products and a number of such product innovations are reported in Luo and Du (2012). Clorox spent three years and more than $20 million to develop its Green Works Line of nonsynthetic cleaning products (Nidumolu et al. 2009). Another example, Levi's, launched its "Water < Less" jeans line in 2011. This came after three years of R&D into techniques to reduce by up to 96% the water used in the manufacturing process, while maintaining the desirable look and feel of Levi's jeans. Table 1 summarizes several examples of socially responsible innovations.

The above initiatives can be seen as R&D investments made by firms in socially responsible products.[2] But why would these investments matter for consumers over and above the economic consumption benefit the product provides? Products such as Water < Less jeans, or a nonsynthetic dishwashing detergent, are not functionally different from their regular product counterparts. This paper identifies two aspects of consumer preferences that affect consumer decisions to

[1] See http://www.greenbiz.com/research/report/2009/04/30/finding-green-todays-shoppers-sustainability-trends-and-new-shopper-insig.

[2] References for the innovations in Table 1 include (a) Clean propulsion for pleasure boats, http://www.iijet.com/IntelliJET%20Development%20History.htm; (b) Waterless jeans: Kaufman (2011); (c) Resuede shoes: Jeffries (2013); and (d) Cosmetics: Lunau (2012).

**Table 1** **Socially Responsible Innovations**

| Company/(Category) | Launch | Description of innovation |
|---|---|---|
| Toyota/(automobiles) | 1997 | Prius: Hybrid propulsion |
| Intellijet boat engines | 2013 | Clean-tech propulsion for pleasure boating, 50% less fuel |
| Clorox/(household products) | 2008 | Green works: Spent $20 million to develop nonsynthetic cleaning products |
| Levi's/(jeans) | 2011 | Water < Less jeans: Over three years of R&D to reduce the amount of water used in manufacturing |
| Puma/(shoes) | 2011 | Puma InCycle, Re-suede Shoes: Footwear made of 100% recyclable materials tied to their "Bring me Back" program |
| Lush/(cosmetics) | 2012 | Three years of R&D to develop a nonpalm oil soap base |

buy socially responsible products. First, as suggested by the Deloitte report, a significant proportion of consumers report an intrinsic desire to reduce the negative impact of their consumption on the environment. They therefore expect socially responsible behavior from firms that would like to sell to them.

A second reason why socially responsible innovations matter for consumers is the value they provide in social interactions. This is illustrated in the following quote (Sorensen 2012, p. 41):

> …hybrid owners are mostly interested in appearing *green*, and that the futuristic-looking Prius was the best car for the job. They called the effect *conspicuous conservation*. The message for carmakers: Even when it comes to the environment, never underestimate the vanity of your customers.

This highlights an extrinsic social role played by these products. Consumers seem to obtain extrinsic social utility from driving a Prius and by comparing themselves to others who drive fuel-inefficient cars. Conspicuous conservation, with the Prius being an important exemplar, is discussed in the popular Freakonomics blog.[3] A recent empirical study by Sexton and Sexton (2014) also shows that the market share of the Prius in green conscious regions of the United States is significantly higher than the market share of equivalent cars like the Honda Accord Hybrid. The study ascribes this to the Prius's unique shape and features, which allow owners to visibly communicate their environmental preferences to others. The study estimates the mean willingness to pay for the green social value provided by the Prius to be in the range of $430–$4,200 depending on the extent of green consciousness in the region. Obviously, the importance of social interactions varies as a function of the category. Referring to Table 1, social interactions are likely to have a stronger impact on categories that are consumed publicly (cars and clothing) and less impact in categories consumed in the privacy of one's home (household cleaning products).

The effects of intrinsic and extrinsic social responsibility preferences on R&D investments although largely unexplored, are related to research in economics and social psychology. In economics, starting with Becker (1974) and later Andreoni (1990, 1995), there is research that considers the role of altruistic (intrinsic) versus social (extrinsic) concerns in the context of public goods and charitable donations. Impure altruism as discussed in Andreoni (1990) is related to two factors that drive people's decisions to donate: the intrinsic motivation (a pure altruistic motive) and the extrinsic motivation (pertaining to the social implications of donating). In psychology, starting with Festinger (1954), there is a stream of research on social comparison where individuals derive value from comparing their consumption with others during social interactions. Product choices can act as a basis for social comparison when the product is visibly consumed (Bearden and Etzel 1982). This paper analyzes the interplay of intrinsic consumer concerns about social responsibility and extrinsic social preferences in a market where firms make R&D investments.

We construct a model in which consumers have social responsibility related preferences in addition to functional or economic product utility. The social responsibility related preferences involve two dimensions. First, consumers incur intrinsic costs (due to altruistic concerns) to consume a socially less responsible product and they are heterogeneous in these costs. Second, consumers have social comparison preferences that are endogenous to the nature of their (random) social interactions with others and to the R&D and pricing choices of firms. Specifically, in our model, consumers enjoy a social comparison benefit when they interact with others whose consumption involves less social responsibility. Conversely, they face a social comparison cost when they interact with others whose consumption involves greater social responsibility.

Given these preferences, we consider the incentives, first of a monopolist and then of competitive firms, to invest in developing socially responsible innovations.

[3] See Dubner (2011) Hey baby, is that a Prius you are driving? *Freakonomics* (July 7), http://freakonomics.com/2011/07/07/hey-baby-is-that-a-prius-you-are-driving/. Other press articles also discuss how the Prius has historically provided the most visible demonstration of the owner's environmental concern of any vehicle in the United States (e.g., *The Washington Post*, August 23, 2004; *TIME*, October 17, 2007; *The New York Times*, July 4, 2007).

The firm first chooses a level of R&D investment and then makes pricing decisions. The investment level determines the probability with which the firm obtains the innovation. The innovation allows the firm to offer a product with a reduced level of the "social bad" (e.g., the extent of environmental damage). The more effective the innovation, the greater is the reduction. As a result, consumers face lower levels of intrinsic costs depending on the effectiveness of the innovation. The social comparison effects depend on the extent to which a consumer's consumption is socially inferior (superior) in a social interaction, and on the probability with which a consumer expects to meet others consuming a different product (or no product at all).

We find that the presence of social comparison costs and benefits adversely affects a monopoly firm's profits whether it sells the innovation or the basic product. Social comparison costs adversely affect the willingness to pay of consumers who purchase the monopolist's product thereby constraining the price that the firm can charge. Social comparison benefits, on the other hand, adversely affect monopoly profits because they are enjoyed by consumers who refrain from buying. Given these adverse effects, how does social comparison impact the incentive of the monopolist to innovate?

We find a nonmonotonic effect of increases in social comparison costs and benefits on the incentive to innovate. When the relative economic value of the product is sufficiently small, social comparison effects reduce the incentive to innovate, whereas they increase innovation incentives when the economic value of the product is sufficiently high. When the economic value is relatively small, there are a larger number of consumers who refrain from buying, which implies a greater probability that a buyer of the innovation interacts with someone who has refrained from buying (which is associated with higher social responsibility). An increase in social comparison effects increases the social comparison cost of a buyer and the social comparison benefit of a nonbuyer and this adversely affects prices and profits. Though these adverse effects on profits are lower for a firm with an innovation, the incremental profits are not commensurate with the cost of R&D so the incentive to innovate decreases. As the relative economic value increases, even socially concerned consumers with high intrinsic costs choose to buy so the probability that a buyer meets a nonbuyer decreases. This reduces the adverse effect of an increase in social comparison costs on prices and profits, and the reduction is even higher for the innovation. The incremental profit of the innovation and the incentive to innovate now increases with social comparison costs. Similarly, the adverse effect of social comparison benefits is sufficiently lower for an innovation compared with the basic product leading to an increase in the incentive to innovate.

The effect of social comparison on the incentive to innovate identified here is based on the role of interactions between nonbuyers and buyers and the idea that the most socially conscious consumers are least likely to buy. The realization that nonbuyer interactions are important for understanding markets for social responsibility is acknowledged by practitioners (see Smith 2013, pp. 16–17). In reality the influences of nonbuyers on buyers may result from several mechanisms. First, in many markets interactions with nonbuyers may affect buyers who are part of the same social community. Often the nonbuying option entails the consumption of an alternative that does not create a social bad (public transit/bicycles as an alternative to cars or sailboats as an alternative to fuel powered motor boats).[4] Second, the increased usage of social media can be a mechanism through which socially conscious nonbuyers can exert influence on buyers of socially irresponsible products. A 2013 Cone Communications study on corporate social responsibility (CSR) documents that as many as 62% of the 10,000 consumers surveyed use some form of social media to engage on CSR issues and 26% are willing to communicate negative information about socially irresponsible firms.[5] Finally, environmentally conscious consumers may even boycott or publicly disparage the manufacturers of environmentally damaging products (an example of this is the well-known campaign waged against Nestle).[6] This can create social costs for those consumers who continue to consume these products publicly.

By extending the analysis to duopoly competition in R&D and then prices, we show that social comparison benefits and costs have different effects on firm competition. Increases in social comparison benefits reduce price competition, whereas increases in social comparison costs do the opposite. In fact, higher social comparison benefits are akin to an increase in differentiation; when social benefits experienced by consumers increase, even a firm with just a basic product realizes higher profit under competition. Furthermore, similar to the monopoly case, we find that social comparison effects mute innovation when the economic value of

[4] In the case of automobiles, this would be relevant for many major cities that have strong public transportation. A large percentage of the population choose not to own cars. Some examples in the United States are San Francisco (31%), New York (56%), and Boston (37%). These markets are also typically at the leading edge of environmental consciousness. In these cities, consumers may refrain from owning cars and social comparison between nonbuyers and buyers is relevant.

[5] As the Executive Vice President (EVP)—Research Insights at Cone Communications mentions consumers using social media are "…poised to not only engage with companies around vital issues, but also serve as CSR megaphones, equally propagating the good and bad." http://www.conecomm.com/2013-global-csr-study-release.

[6] See, for example, http://metro.co.uk/2010/03/18/kitkats-are-killing-endangered-orangutans-176442/.

the product is low and stimulate innovation when the economic value of the product is high.

Comparing innovation incentives, firms under competition have a stronger incentive to innovate than a monopoly when the economic value of the product is relatively low, whereas the reverse is true when the economic value is relatively high. The result is due to the interplay of the replacement effect (i.e., the profit from the innovation replaces profit that could be earned with the basic product) and the competitive effect from introducing an innovation. When the economic value is relatively low, the replacement effect is significant for a monopolist, whereas it is smaller under competition. Furthermore, the degree of competition facing a firm with an innovation is lower. This leads to greater innovation incentives under competition. By contrast, when the economic value of the product is relatively large, the degree of competition facing the firm with the innovation is higher. However, here the replacement effect for a monopoly firm is weaker and the monopolist with the innovation is able to capture a larger amount of incremental profit.

### 1.1. Related Research

The classic article by Friedman (1970) argues that personal altruism should not play a role in the decision making of managers: the responsibility of corporations is to maximize profits and shareholder value while conforming to the rules of law. There is also a literature that argues for the role of corporate social responsibility given the evidence that companies do engage in charity or social causes (Vogel 2005). A frequent rationale provided is that consumers prefer brands associated with social causes.[7] Consistent with this, there is empirical literature that finds a positive demand effect for socially responsible brands (e.g., Sen and Bhattacharya 2001) and suggests that altruistic preferences on the part of consumers (rather than managers) motivates responsible behavior on the part of firms. Our paper models how the intrinsic/altruistic concerns of consumers and social comparison preferences (arising out of interactions between consumers) affect R&D decisions.

Among existing research on CSR initiatives, a paper by Baron (2001) examines CSR by firms in response to a threat by an activist or to consumer activism (consumers boycott goods that are perceived as socially irresponsible). Consumer activism or boycotts in our framework can be seen as a mechanism through which nonbuyers influence buyers about products that they perceive as socially irresponsible. Some papers propose strategic rationales for CSR: Banerjee and Wathieu (2013) analyze the role of CSR in a context where advertising can signal product quality. Branco and Villas-Boas (2015) consider competition between firms when they are required to follow rules determined by law or by social practice and argue that greater competition may lead firms to invest less in following rules. In this paper, we examine the incentives for socially responsible innovation where the drivers of consumer preference are consumers' intrinsic desire to reduce a social bad and consumers' extrinsic need to publicly consume socially responsible products.

There are conceptual differences between the role of social interactions in the fashion goods literature and our analysis of socially responsible innovations. In Pesendorfer (1995), the idea is that if the consumption of a fashionable item is removed from its specific social context, then changes in fashion do not entail an improvement in product quality. In other words, the value of fashion does not pertain to increases in functional product quality, whereas the value of social responsibility is based on a product attribute that has functional value (i.e., reducing the damage to the environment). In our model, it is along this dimension that consumers are heterogeneous. In fashion goods models, consumers buy fashion either to signal their (high) type (Pesendorfer 1995) or to communicate their fit with consumers of the same type in a matching game (Kuksov 2007).[8] The basis of our model is different than the signaling rationale of the fashion goods literature: social comparison means that consumers obtain benefits or costs because of interaction with others who have a different product. Finally, in our model, because consumers incur intrinsic costs to consume an environmentally inferior product, refraining from buying is the most desirable behavior in terms of social responsibility. In fact, the most socially conscious nonbuyers incur no social comparison cost and enjoy social comparison benefits. An implication of the potential value of not buying is that markets for socially responsible products are similar to markets for positional goods (Frank 1985). Consumers enjoy a social comparison benefit if they interact with someone who consumes a product that is inferior on the social responsibility dimension, whereas they incur a social comparison cost if they interact with someone who consumes a superior product on the social responsibility dimension.

There is also research that considers the role of exclusivity and conformity through social interactions in fashion markets. Amaldoss and Jain (2005) model a firm's pricing decisions in markets with social interactions when some consumers have social value for

[7] Some papers (e.g., Krishna and Rajan 2009, Arora and Henderson 2007) analyze the incentives of firms to contribute to a cause because it is assumed that consumers are willing to pay more for a product that is associated with the cause.

[8] Similarly, in Yoganarasimhan (2012), the fashion good helps an individual in a matching game to fit in or to differentiate by signaling the individual's taste to others.

exclusivity (their product utility decreases with the number of others who buy it) whereas others follow the bandwagon and have higher utility for a product when many people buy it. Another paper by Balachander and Stock (2009) models the preference for exclusivity and looks at the incentive of firms to limit quantity and offer limited edition products. In our paper, the social interaction component of consumer preferences for social responsibility does not relate to the taste for exclusivity, but rather to the costs and benefits of social comparisons based on the products purchased.

Finally, our paper is related to the literature on investment by firms in R&D, which has its origins in Arrow (1962). Subsequently, the literature has distinguished between the incentive to innovate for a monopolist versus that for competitive firms (see Dasgupta and Stiglitz 1980, Gilbert and Newbury 1982). The focus of this paper is product innovations that reduce a social bad that concerns consumers and the incentives of firms to supply these innovations. In addition, we analyze how the magnitude of the social comparison costs and benefits and the economic value of the product affect innovation incentives.

The rest of the paper proceeds as follows: Section 2 describes the model, and in Section 3 we analyze the monopoly incentives to supply social innovation. Section 4 examines how social responsibility preferences affect the incentives of two competing firms to innovate. In Section 4.2 we analyze a competitive fringe extension to understand how the incentives to innovate are altered when a firm faces a perfectly competitive market for the basic product. We conclude in Section 5.

## 2. The Main Model

We begin by describing a market without the innovation. The firm has a basic product whose economic value to consumers is $v$. The economic value is the consumer's value for the functional and quality related aspects of the product. The marginal cost of production is constant and set to zero. The consumption of each unit of the basic product is assumed to cause one unit of social bad, which can include the environmental costs of producing the product or any cost created by the consumer's product usage and consumption. Consider a firm that has an innovation that reduces the extent of the social bad/environmental damage that consumption of the product entails. The degree to which the innovation is an improvement over the basic product is represented by $\delta \in (0, 1)$, which is the fraction of environmental damage created by the new product. Thus an innovation with $\delta = 0$, completely eliminates the social bad/environmental damage associated with the basic product.

### 2.1. Consumer Preferences

The market consists of a unit mass of consumers who choose whether or not to purchase one unit of product given the price(s) they observe. Every product (socially responsible or not) delivers an economic consumption value $v$ to the consumer, if purchased. In addition, consumers have social preferences along two dimensions: first, they have intrinsic or altruistic preferences represented by a cost $t$ for the social/environmental bad created by their consumption. Consumers are heterogeneous in these costs, which are uniformly distributed in the interval $(0, 1)$. Note that the intrinsic cost felt by a consumer depends on whether she is consuming the basic product or the innovation: for the basic product, the cost is $t$ and for the innovation it is $\delta t$. Second, consumers have social comparison preferences that can imply benefits and/or costs. The benefits and costs are endogenous to the product that is consumed and the nature of their social interactions with other consumers. Social comparison preferences are positional in nature so a consumer only incurs benefits or costs if she meets a person whose consumption is superior or inferior along the social responsibility dimension compared to her own. Furthermore, the costs and benefits are proportional to the extent by which a consumer's consumption is superior or inferior to that of the other. Each consumer is assumed to randomly interact with others in the market.[9] This assumption represents large atomistic markets where the probability of meeting another randomly drawn individual in the population is equal and consumers do not fully control their social encounters.

We first analyze a main model with symmetric social comparison effects. Let $k$ denote the intensity of the social comparison effect. If a consumer buys the basic product (which creates one unit of social bad) and randomly encounters a consumer who has refrained from buying (and so creates no social bad), she incurs a social comparison cost of $k$, whereas upon meeting a consumer with the innovation, she incurs a social comparison cost of $k(1-\delta)$. If the consumer were to buy the innovation she would incur a (lower) cost of $\delta k$ when she meets a consumer who refrains from buying. In other words, the social comparison costs incurred by a consumer depend on $k$ and the difference in social bad created by her consumption and the other consumer in the interaction.

[9] In some markets, consumers may be more likely to interact with others who have similar preferences. We have considered a model with nonrandom social interactions where consumers encounter others of the same type with probability $\alpha$, and with probability $1-\alpha$ encounter someone randomly in the interval $(0, 1)$. In this setup, the social comparison effects are progressively weakened as $\alpha$ increases and the interactions become local. When $\alpha = 1$, the decisions of consumers are driven entirely by intrinsic preferences. Details of this analysis are available from the authors.

Consider next, social comparison benefits. If a consumer buys the innovation (which creates $\delta$ units of environmental damage) and meets a consumer who buys the basic product, she experiences a social comparison benefit of $k(1-\delta)$. Similarly, if a consumer who chooses not to buy encounters another who buys the basic product, she obtains a social comparison benefit of $k$, whereas if she meets a consumer who buys the innovation she obtains a benefit of $k\delta$. In aggregate, the social comparison effects felt by an individual are proportional to the interaction probabilities of meeting people whose consumption choices are different. These probabilities are endogenous to market demand and therefore endogenous to the R&D and pricing actions of the firms.

Note that the analysis has a role for nonbuyer interactions. Consumers who refrain from buying are by definition those who have high intrinsic costs and therefore the ones who are the most socially conscious. Therefore, buyers of products feel social comparison costs in encounters with nonbuyers, whereas nonbuyers enjoy social comparison benefits. As discussed in Section 1, the interactions between nonbuyers and buyers arise from the use of a visible alternative (for example, public transit in the case of automobiles), the frequent use of social media to communicate about socially irresponsible behavior by firms, or boycotts and consumer activism against products that are seen as socially damaging.

We allow consumers to be heterogeneous in their intrinsic costs, but not along the social comparison dimension. This reflects the idea that social comparison effects tend to be specific to product categories. For example, Della Vigna et al. (2012) show that consumer decisions are affected by external needs when the category is highly visible to other consumers. As noted earlier, social comparison effects should be stronger in categories like clothing and cars versus household cleaning products and packaged foods. Accordingly, $k$ is representative of the degree to which the product category is visible and consumed publicly.

### 2.2. Firm(s) Decisions and Timing

In the first stage of the game, the firm makes an R&D decision $w$ and $w \in (0,1)$. This represents the success probability by which the firm realizes the innovation. A firm with the innovation can sell a product that reduces the environmental damage by a fraction $\delta \in (0,1)$. The cost of R&D is increasing and convex: $c(w) = \beta w^2$.[10] In the case of duopoly competition, the firms $j = 1, 2$ simultaneously choose $w_j$ in the first stage. Then in the second stage after observing the R&D outcomes, the firm(s) make pricing decisions (in the case of competitive firms the prices $p_j$ are chosen simultaneously). In stage 3, upon observing the available products and prices, consumers form expectations about demand and the probabilities of the relevant social interactions and make their buying decisions. We solve for the subgame perfect equilibrium of this game such that consumer expectations of demand are rational and consistent with the equilibrium.

[10] We assume that the cost of R&D $\beta$ is sufficiently high such that even under monopoly $w^* < 1$, i.e., there is uncertainty about whether or not the firm obtains the innovation.

## 3. Innovation Under Monopoly

After the R&D decision, the firm is either successful ($s$) or unsuccessful ($u$) and it chooses contingent prices $p_s$ or $p_u$ in the second stage accordingly. Consider the case of a firm with the innovation charging a price $p_s$. A consumer of type (intrinsic cost) $t$ who considers purchasing the innovation expects a surplus of

$$\mathrm{CS}_{sb} = v - \delta t - \delta k(1-\tilde{t}) - p_s. \quad (1)$$

The second term $-\delta t$ represents the intrinsic cost faced by a type $t$ consumer when consuming the innovation: the innovation reduces the environmental damage by $\delta$ compared to the basic product. The third term represents the social comparison costs expected by the consumer. The consumer's expectation of the marginal consumer type who is indifferent between buying and not buying is denoted by $\tilde{t}$. Therefore, $(1-\tilde{t})$ is the consumer's assessed probability of a random social interaction with a nonbuyer.

Next, consider the surplus of a consumer that refrains from buying, but who expects to encounter buyers

$$\mathrm{CS}_{s(nb)} = \delta k \tilde{t}. \quad (2)$$

Note that the nonbuyer will meet a buyer with probability $\tilde{t}$ and enjoy a social comparison benefit. Because the innovation reduces the environmental damage by $\delta$, the expected social benefit is equal to $\delta k \tilde{t}$. Consumer expectations in the third stage upon observing the firm's price $p_s$ (and the product's $\delta$) must be rational. Therefore, we calculate the optimal demand as a function of the firm's decisions by equating (1) and (2), and then setting $t = \tilde{t} = \hat{t}_s$, to obtain $\hat{t}_s = (v - p_s - \delta k)/\delta$. Next, consider the case of a firm without the innovation that sells the basic product and charges a price $p_u$. We derive the relevant consumer surplus functions for the basic product by using $\mathrm{CS}_{ub} = \mathrm{CS}_{sb}(\delta = 1)$ and $\mathrm{CS}_{u(nb)} = \mathrm{CS}_{s(nb)}(\delta = 1)$. From this, the optimal demand for the basic product (as a function of the firm's pricing decision) is $\hat{t}_u = v - p_u - k$.

Given consumer decisions and the derived demand, we now examine firm actions and the equilibrium of the game. After the firm has chosen its investment $w$ in the first stage, there are two possible outcomes. When the R&D is successful, the innovation is available and it reduces the environmental damage by $\delta$ or, when the R&D is unsuccessful, the firm only has the basic product. When the firm only has the basic product, we assume that it does not sell to all consumers. In other words, with the basic product some socially conscious consumers (with high enough $t$) choose not to buy. This assumption creates a rationale for the firm to innovate: so that more socially conscious consumers can be served. Partial coverage of the market without the innovation implies that $k < v < 2 + k$ (the lower bound is necessary for positive prices). The firm's profit when R&D fails is $\pi_u = p_u \hat{t}_u$. We calculate the second-stage equilibrium profits of the monopolist without the innovation to be $\pi_u = (v - k)^2/4$.

Next, if the R&D is successful, the firm has the option to sell a product line with the basic product and the innovation. However, when the marginal cost of the basic product and innovation are the same, it is optimal for the firm to sell only the innovation.[11] The firm's profit when R&D is successful is given by $\pi_s = p_s \hat{t}_s$. The following lemma summarizes the outcomes for the firm in the subgame where it has the innovation (the appendix shows the derivations).

Lemma 1. *For a monopolist with an innovation of effectiveness* $\delta$, *we have, in equilibrium, the following*:

1. *If* $k < v < \delta(2 + k)$, *then* $t_s^* = (v - \delta k)/(2\delta)$, $p_s^* = (v - \delta k)/2$, *and* $\pi_s^* = (v - \delta k)^2/(4\delta)$.
2. *If* $v > \delta(2 + k)$, *then* $t_s^* = 1$, $p_s^* = v - \delta(1 + k)$, *and* $\pi_s^* = v - \delta(1 + k)$.

Firm profits are adversely affected by the strength of social comparison effects. Even with the innovation, a monopolist would rather operate in a market where consumers did not experience social comparison. Greater social comparison costs reduce the willingness to pay for consumers who buy the product and greater social comparison benefits increase the attractiveness of not buying.

The first stage of the game is the monopolist's R&D decision. The first-stage expected profit function of the monopolist is

$$\Pi_i = w\pi_s^* + (1 - w)\pi_u^* - \beta w_i^2. \tag{3}$$

From this, the optimal incentive to innovate is $w^* = (\pi_s^* - \pi_u^*)/(2\beta)$. The monopoly firm's incentive to innovate is governed by the incremental profit of successful R&D over and above the profits earned with the basic product. This underscores the replacement effect faced by a monopolist; the monopolist loses the profit earned with the basic product when the innovation is introduced. Thus, the magnitude of profits earned with only the basic product affects the firm's incentive to innovate. In the following proposition, we specify how the strength of social comparison affects innovation incentives.

Proposition 1. *The equilibrium level of innovation* $w^*$ *is impacted by social comparison effects as follows*:

1. *If* $k < v < k + 2\delta$, *then* $\partial w^*/\partial k < 0$.
2. *If* $k + 2\delta < v < 2 + k$, *then* $\partial w^*/\partial k > 0$.[12]

Proposition 1 shows the nonmonotonic impact of social comparison effects on innovation incentives. When the economic value of the product is relatively low ($k < v < 2 + k$), increases in $k$ reduce innovation incentives, whereas when the economic value is high, increases in $k$ increase innovation incentives. The intuition is as follows: the incentive to innovate is determined by the incremental profit generated by the innovation. When the economic value of the product is relatively low, there is a large number of consumers who refrain from buying. Therefore, the interaction probability of a buyer meeting a nonbuyer is high. An increase in $k$ increases the social comparison cost of a buyer and the social comparison benefit of a nonbuyer. This lowers the price and profits of the firm. Although the adverse effects on profits are lower for a firm with an innovation, the incremental profits are not commensurate with the cost of R&D. Thus, when the economic value of the product is relatively small, increases in social comparison effects reduce the incentive to innovate.

As the economic value of the product increases, even socially concerned consumers with high intrinsic costs choose to buy. This reduces the interaction probability that a buyer meets a nonbuyer. Thus, the adverse effect of increases in the social comparison cost on price is lower; at the extreme, this adverse effect vanishes when all consumers are served. The positive impact of this probability effect on firm profits is higher with the innovation than without and this increases the incentive to innovate. Similarly, when economic value of the product is sufficiently high, the adverse effect of social comparison benefits is reduced compared to the basic product. As a result, the overall effect of higher social comparison effects here, is to increase the incentive to innovate.

### 3.1. Asymmetric Social Comparison Effects

In this section, we separate the effects of the social comparison costs and benefits. This allows us to untangle the effects of social comparison costs and benefits on the incentive to innovate. It also allows us to examine conditions where the costs and benefits are asymmetric. There are categories where social comparison costs

[11] In Section 3.2, we identify conditions where a monopoly will market a product line. This obtains when the marginal cost of producing the innovation is significantly higher than that of the basic product.

[12] The right limit of the interval ensures that in the event the R&D is unsuccessful, the basic product cannot fully cover the market.

**Table 2 Social Comparison Costs and Benefits When $k_b \neq k_c$**

| Buyer type | Basic product buyers | Buyers of innovation | Nonbuyers |
|---|---|---|---|
| Social comparison cost | $k_c(1-\delta)(\tilde{t}_2-\tilde{t}_1)+k_c(1-\tilde{t}_2)$ | $k_c\delta(1-\tilde{t}_2)$ | 0 |
| Social comparison benefit | 0 | $k_b(1-\delta)\tilde{t}_1$ | $k_b\tilde{t}_1+k_b\delta(\tilde{t}_2-\tilde{t}_1)$ |

may be relatively more important than social comparison benefits, and vice versa. To be specific, in some markets the negative effects (and the associated social comparison cost) are more salient. Such would be the case for large motor vehicles in an extremely green conscious community. Other categories may be more characterized by positive effects and the associated social comparison benefits. Such might be the case in the jeans market: someone wearing the Water < Less or the Waste < Less labels would enjoy social comparison benefits, but someone wearing regular Levi's jeans would not likely suffer from social comparison costs of equivalent intensity. Accordingly, we consider a model where the intensity of social comparison benefits and costs are denoted by $k_b$ and $k_c$, respectively (in general $k_b \neq k_c$). Table 2 summarizes the social comparison costs and benefits for different consumers.

The equilibrium for a firm with the innovation is given in Lemma 2.

Lemma 2. *For monopoly with an innovation of effectiveness $\delta$, we have, in equilibrium, the following*:

1. If $k_c < v < \delta(2(1+k_b)-k_c)$, then $t_s^* = (v-\delta k_c)/(2\delta(1+k_b-k_c))$, $p_s^* = (v-\delta k_c)/2$, and $\pi_s^* = (v-\delta k_c)^2/(4\delta(1+k_b-k_c))$.
2. If $v > \delta(2(1+k_b)-k_c)$, then $t_s^* = 1$, $p_s^* = v-\delta(1+k_b)$, and $\pi_s^* = v-\delta(1+k_b)$.

When the economic value of the product is low, the equilibrium price charged decreases with $k_c$ and is independent of $k_b$. When some socially conscious consumers do not buy, an increase in $k_c$ induces the firm to reduce the price so as to retain demand. Conversely, firms do not reduce the price in response to an increase in $k_b$. Were a firm to reduce the price in response to an increase in $k_b$, there are two effects. First, demand for the firm's product would increase. Second, the interaction probability for a potential nonbuyer with a buyer increases; this raises the nonbuyer's social comparison benefit (and has a negative effect on demand). These two effects cancel each other so the firm's marginal revenue and price are independent of $k_b$. Intuitively, not responding with a price cut when faced with an increase in $k_b$ is a way for the firm to not increase the social comparison benefit of nonbuyers.

By contrast, when the economic value of the product is relatively high and even the most socially conscious consumers buy the innovation, the equilibrium prices and profits are independent of $k_c$ but decrease in $k_b$. Increases in $k_c$ do not affect prices because the probability that a buyer meets a nonbuyer diminishes and goes to zero in the extreme. However, the marginal nonbuyer now interacts with a buyer with probability close to or at one and so increases in $k_b$ reduce the optimal price for the firm.

We now move to the first stage of the game and the firm's R&D decision. The optimal incentive to innovate when $k_c < v < \delta(2(1+k_b)-k_c)$ is $w^* = (1-\delta)\cdot(v^2-\delta k_c^2)/(8\delta\beta(1+k_b-k_c))$. Under full coverage of the market when $v > \delta(2(1+k_b)-k_c)$, the optimal level of innovation is $w^* = ((v+k_c)^2+4(1+k_b)(v+\delta(1+k_b-k_c)))/(8\beta(1+k_b-k_c))$. Proposition 2 summarizes the effect of social comparison costs on the innovation incentives.

Proposition 2. *The equilibrium level of innovation $w^*$ is impacted by social comparison costs and benefits as follows*:

1. *When $k_c < v < \sqrt{\delta k_c(2+2k_b-k_c)}$, then $\partial w^*/\partial k_b < 0$ and $\partial w^*/\partial k_c < 0$.*
2. *When $\sqrt{\delta k_c(2+2k_b-k_c)} < v < k_c+2\sqrt{\delta}(1+k_b-k_c)$, then $\partial w^*/\partial k_b < 0$ and $\partial w^*/\partial k_c > 0$.*
3. *When $k_c+2\sqrt{\delta}(1+k_b-k_c) < v < 2(1+k_b)-k_c$, then $\partial w^*/\partial k_b > 0$ and $\partial w^*/\partial k_c > 0$.*

This proposition untangles the effects of social comparison costs and benefits and provides intuition for an important finding of the paper: the manner by which the relative economic value of the product and social comparison preferences affect the incentive to innovate. When the relative economic value is low, increases in both $k_c$ and $k_b$ lead to higher incremental profits with the innovation relative to the cost of innovating and so the firm decreases $w^*$. The converse is true when the relative economic value is sufficiently high.

Suppose that the relative economic value is sufficiently high such that most consumers in the market buy the innovation. The firm with the innovation suffers a negligible reduction in its equilibrium price and profits when $k_c$ increases. At the extreme, when all consumers buy, the profits of the innovator become insensitive to increases in $k_c$. By contrast, if the R&D is unsuccessful, the profit of the basic product is more sensitive to increases in $k_c$. Therefore, the incremental profits of the innovation over the basic product increase with $k_c$ compared with the cost of innovating, which increases the incentive to innovate. When the relative economic value is low, a significant fraction of the market does not buy even when the innovation is available. This makes the price and profits of the innovation more sensitive to increases in social comparison costs:

an increase in social comparison costs causes a greater drop in profits. As a result, the incremental profit with the innovation over the basic product is smaller compared to the cost of innovating. The incentive to innovate decreases with increases in $k_c$.

Turning to the effect of social comparison benefits, recall from Lemma 2 that the price that the firm charges is unaffected by an increase in $k_b$ when the economic value of the product is relatively low. Yet the incremental demand for the innovation over the basic product decreases as $k_b$ goes up. As a result, the incremental profit of the innovation over the basic product and the firm's incentive to innovate decrease with social comparison benefits. When the economic value is high such that all consumers in the market buy the innovation, the demand for the innovation is invariant to increases in $k_b$, whereas that of the basic product decreases leading to greater incremental demand for the innovation. For large enough $v$, this greater incremental demand implies more incremental profit from the innovation and a higher incentive to innovate.

Proposition 2 provides another result about the relative effects of social comparison costs and benefits. Note from parts 2 and 3 of Proposition 2 that $\partial w^*/\partial k_c$ becomes positive earlier in the range than $\partial w^*/\partial k_b$. In other words, there is a greater range of markets where increases in social comparison costs motivate firms to innovate compared with increases in social comparison benefits. As market coverage increases, the negative effect of $k_c$ is muted more quickly because of a lower interaction probability between a buyer and nonbuyers. By contrast, as the economic value of the product increases, the interaction probability between a nonbuyer and buyers is higher; this explains a continuing negative effect of $k_b$ on profits. It is only when $v$ is sufficiently high such that coverage is full and demand is inelastic that increases in $k_b$ also have a positive effect on the incentive to innovate (the reduction in the innovator's profits for an increase in $k_b$ is less than the reduction for the basic product). This implies that exogenous shocks/events that highlight the social comparison costs of a product to the public may have a greater impact in motivating firms to invest in social innovation than events that highlight the social comparison benefits.

### 3.2. Marginal Costs for the Innovation

In the main model, we analyze a situation where the marginal cost for the innovation and the basic product are identical. This reflects the idea that the main costs of creating and selling socially responsible innovations are upfront R&D investment costs, rather than marginal cost differences. That being said, our review of socially responsible innovations identifies some examples where the innovation may be either *less* or *more* expensive to produce. Examples of innovations where the marginal cost was similar (or even reduced) include jeans produced with less water (Water < Less jeans) and footwear made with recycled material (Puma InCycle shoes). Conversely, in some categories, producing the innovation implies additional marginal production costs. For example, socially responsible automobiles (based on hybrid engine technology or electric battery technology) are more expensive to manufacture than the standard internal combustion engine (at least early in the life cycle of the new technology).

To assess the impact of marginal costs, we consider an extension in which the marginal cost of production is higher for the innovation than for the basic product, i.e., the marginal cost of the innovation is $c > 0$ and the marginal cost of the basic product is zero.

Proposition 3. *If the R&D is successful and the firm has the innovation, then in equilibrium, we have the following*:

1. *When* $0 \leq c < k(1-\delta)$, *the firm only sells the innovation and discontinues the basic product*.
2. *When* $k(1-\delta) < c < (v + \sqrt{\delta}k)(1-\sqrt{\delta})$, *the firm sells a product line consisting of both the innovation and the basic product*.

As long as the marginal cost difference between the innovation and the basic product is sufficiently small, the result of the main model holds; the firm launches the innovation to replace the basic product. It is when the cost difference is sufficiently high, $c > k(1-\delta)$, that it is optimal to launch a product line. A product line strategy is more likely when $k$ is relatively low: i.e., when the intrinsic preferences are high compared to the extrinsic social comparison effects. Here, the product line has value in terms of allowing the firm to screen consumers who are heterogeneous in their intrinsic cost for social responsibility. However, even with the possibility of a product line, the main results pertaining to the effects of social comparison preferences on innovation incentives are preserved.[13]

An example that relates to these findings is Clorox's initiative mentioned in Table 1. Clorox developed its Green Works line after market research revealed that household cleaning products are considered the second most important environmental concern of consumers in the grocery category. Although Clorox spent $20 million on R&D to develop the line, Green Works

[13] It may also be noted that if there exists horizontal differentiation in the model (in addition to the heterogeneity in intrinsic costs), then competing firms might offer the product line in equilibrium. Incorporating horizontal differentiation would not qualitatively affect the results pertaining to the innovation incentives and the role of social comparison preferences. At one extreme, if horizontal differentiation is high and firms have local market power, we obtain a case similar to the monopoly analysis of this paper. Conversely, if horizontal differentiation is small, we obtain a case similar to the duopoly analysis of Section 4.

products require raw materials that are more expensive. Clorox continues to market both its traditional cleaning products and the Green Works line. The Green Works products sell at a premium of approximately 15% to 25% reflecting higher production costs. This is consistent with our analysis: cleaning products used within the home may be seen as a product category for which the intrinsic costs are relatively more important than social comparison concerns. This coupled with higher production costs provides the incentive to sell a product line.

Furthermore, with many sustainability initiatives, the stated objective of management is to work toward reducing the production costs over time, eventually to levels below the cost of current products. This idea of viewing sustainability as an opportunity to reduce production costs over time is articulated in numerous industry examples (Nidumolu et al. 2009). A testable implication from our analysis, is that early in the life cycle of socially responsible innovations, firms are more likely to sell a product line, whereas over time, as costs go down, firms may decide to sell only the innovation.

# 4. Innovation Under Imperfect Competition

We now extend the analysis to duopoly competition between firms in both R&D and prices. Because untangling the effects of social comparison costs and benefits is important, we use the general model with asymmetric costs and benefits. In the first stage, firms simultaneously choose their R&D investments $w_i$ $(i = 1, 2)$. Given the simultaneity of the investment choices, there are three possible outcomes in the pricing subgame. If both firms have unsuccessful R&D, then they both compete with the basic product, and if both firms have successful R&D they both have the innovation in stage 2. In both of these cases, firms compete in Bertrand fashion in the subgame.[14] Finally, when only one firm's R&D is successful, the firms compete with differentiated products. When there is competition between one firm with the innovation and the other with the basic product, the surplus functions for a consumer of type $t$ are as follows (as before, the subscripts $s$ and $u$ denote the innovation and the basic product, respectively):

$$\mathrm{CS}_s = v - \delta t - p_s + k_b(1-\delta)\tilde{t}_1 - k_c\delta(1-\tilde{t}_2), \tag{4}$$

$$\mathrm{CS}_u = v - t - p_u - k_c(1-\tilde{t}_2) - k_c(1-\delta)(\tilde{t}_2 - \tilde{t}_1), \tag{5}$$

$$\mathrm{CS}_{nb} = k_b\delta(\tilde{t}_2 - \tilde{t}_1) + k_b\tilde{t}_1. \tag{6}$$

[14] When both firms have the innovation, it might be asked, can one firm voluntarily ex post withdraw the innovation that it has already launched and instead sell the basic product? At the end of this section, we discuss the implication of allowing a firm to ex post withdraw its innovation.

Here, (4) is the surplus of the type $t$ consumer who buys the innovation, (5) is the surplus of the consumer who buys the basic product, and (6) is the surplus of the consumer who chooses not to buy. The indifference condition for the marginal consumer between buying the innovation and not buying is obtained by equating (4) and (6). Given rational consumer expectations, $t = \tilde{t}_2 = \hat{t}_2$ in equilibrium so $\hat{t}_2 = (v - p_s - \delta k_c)/(\delta(1 + k_b - k_c))$. Similarly by equating (4) and (5), we obtain $t = \tilde{t}_1 = \hat{t}_1$ in equilibrium and from this we derive $\hat{t}_1 = ((p_s - p_u) - (1-\delta)k_c)/((1-\delta)(1 + k_b - k_c))$. The profit functions for the firms when $\hat{t}_2 < 1$ are $\pi_s = (\hat{t}_2 - \hat{t}_1)p_s$ and $\pi_u = \hat{t}_1 p_u$. The condition for $\hat{t}_1 > 0$ is $v > 2k_c$. The equilibrium is summarized in Proposition 4.

Proposition 4. *When one firm has the innovation and the other firm has the basic product, the second-stage equilibrium implies the following:*

1. *When* $2k_c < v < \delta((4-\delta)(1+k_b) - (1-\delta)k_c)/(2+\delta)$, *the profits of the firm with the innovation and the firm with the basic product both decrease with increases in* $k_b$ *and* $k_c$.
2. *When* $\delta((4-\delta)(1+k_b) - (1-\delta)k_c)/(2+\delta) < v < (1+k_b)$, *the profits of the firm with the innovation increases with increases in both* $k_c$ *and* $k_b$. *By contrast, the profits of the firm with the basic product decreases with* $k_c$ *but increases with* $k_b$.

When the economic value of the product is sufficiently low and there are a significant number of nonbuyers, increases in social comparison costs intensify price competition resulting in lower profits for both firms. The equilibrium prices are $p_s^* = (1-\delta)(2v - \delta k_c)/(4-\delta)$ and $p_u^* = (1-\delta)(v - 2k_c)/(4-\delta)$. As $k_c$ increases, there is an unambiguous incentive for the firm with the basic product to reduce price not only because it stems the loss of demand but also because it reduces the probability that a consumer with the basic product interacts with those who either purchased the innovation or with nonbuyers. Consequently, increases in $k_c$ reduce $p_u$, and because prices are strategic complements, the firm with the innovation responds by reducing its price as well. An increase in $k_b$ also reduces the equilibrium profits of both firms, albeit through a different mechanism. Although the equilibrium prices are unaffected by $k_b$, when $v$ is not too high, increases in social comparison benefits make the option of not buying more attractive and this reduces the demand of both firms.

Part 2 of Proposition 4 shows that the nature of the equilibrium is qualitatively different when the economic value of the product is high. Higher social comparison costs now confer a competitive advantage to the firm with the innovation whose profits increase with $k_c$, whereas the profits of the basic product are adversely affected. By contrast, increases in social comparison benefits reduce competition and increase the profits of both firms. To understand why, consider the behavior of the equilibrium prices: $p_s^* = (1-\delta)(2 + 2k_b - k_c)/3$ and $p_u^* = (1-\delta)(1 + k_b - 2k_c)/3$. An increase in $k_c$ has a negative effect on the basic product's valuation and this leads to a reduction in $p_u^*$. The strategic complementarity of prices induces the firm with the innovation to reduce its price (but to a lesser extent). Similar to part 1 of Proposition 4, increases in $k_c$ intensify price competition. Yet in addition, the equilibrium demand of the firm with the innovation increases with $k_c$ (because it gains on the margin from the firm with the basic product without losing demand at the no purchase margin) whereas that of the firm with the basic product decreases. Thus, increases in $k_c$ create a competitive advantage for the firm with the innovation despite intensified price competition.

Turning to the effect of $k_b$, when the economic value is high, and most (or all) consumers buy in equilibrium, the firm with the innovation faces only a positive effect of $k_b$ when its buyers interact with the buyers of the basic product. Thus, the price of the innovation increases with $k_b$. Through the strategic complementarity of prices, this induces the firm with the basic product to also increase its price. As a result, an increase in social comparison benefits softens the intensity of price competition and increases the profits of both firms. Nonbuyers do place a negative externality on firms by forcing the firm with the innovation to reduce their price. Yet when $v$ is high, the negative externality placed by nonbuyers on the firms is muted. This, coupled with the fact that increases in $k_b$ soften price competition, leads to increases in the equilibrium profits of both firms. To summarize, social comparison benefits can be a "good" for both firms under differentiated competition because they mitigate price competition. Furthermore, though social comparison costs exacerbate price competition, they can also be a source of competitive advantage for a firm with the innovation.

We now move to the first stage of the game where both firms make R&D decisions $w_i$ $(i = 1, 2)$. Firm $i$'s first-stage expected profit function is

$$\Pi_i = w_i(1 - w_{-i})\pi_s + (1 - w_i)w_{-i}\pi_u - \beta w_i^2. \quad (7)$$

The symmetric Nash equilibrium of the first-stage game in R&D investments is $w^* = \pi_s/(\pi_s + \pi_u + 2\beta)$.[15] The incentive to innovate under competition is a function of how large the innovation profits are compared to the total profits earned by both firms. Proposition 5 starts by examining the effect of social comparison costs, $k_c$.

[15] For completeness, note that if $\beta$ is sufficiently small, there exist asymmetric equilibria in which one firm invests to obtain the innovation with certainty, whereas the other chooses not to invest at all. However, the threshold of $\beta$ below which the asymmetric equilibria occur is less than the minimum threshold of $\beta$ required in the monopoly case to avoid the degenerate case that the monopoly innovator invests to obtain the innovation with certainty.

Proposition 5. *The comparative statics for $w^*$ with respect to $k_c$ are as follows*:

1. *When $2k_c < v < \delta(2 + 2k_b - k_c)/2$, then $w^*$ is decreasing in $k_c$ if the cost of innovation $\beta$ is sufficiently large, and is otherwise increasing*.
2. *When $\delta(2 + 2k_b - k_c)/2 < v < (1 + k_b)$, then $w^*$ is increasing in $k_c$*.

Social comparison costs have a negative effect on the incentive to innovate under competition when the economic value of the product is not too high and when the cost of innovating is sufficiently high. Here, a firm contemplating the choice of R&D effort, contends with the fact that nonbuyers place a negative externality on the buyers of the innovation. This negative externality increases with $k_c$ and decreases the incremental profit from the innovation and so the incentive to innovate decreases. By contrast, when the economic value of the product increases and more consumers buy, the negative externality placed by potential nonbuyers on the buyers of the innovation is smaller. As shown in part 2 of Proposition 4, increases in $k_c$ confer a competitive advantage for the firm if it has the innovation. Thus the equilibrium innovation level increases with $k_c$. Proposition 6 presents the effect of $k_b$ on the innovation incentives under competition.

Proposition 6. *The comparative statics for $w^*$ with respect to $k_b$ are as follows*:

1. *When $2k_c < v < \delta((4 - \delta)(1 + k_b) - (1 - \delta)k_c)/(2 + \delta)$, then $w^*$ is decreasing in $k_b$*.
2. *When $\delta((4 - \delta)(1 + k_b) - (1 - \delta)k_c)/(2 + \delta) < v < (1 + k_b)$, then $w^*$ is increasing in $k_b$ as long as the costs of innovation ($\beta$) are large enough*.

As the economic value of the product increases, the impact of $k_b$ moves from having a negative effect on the incentive to innovate to having a positive effect. The proposition also identifies some additional effects. When $v$ is sufficiently high, the incentive to innovate $w^*$ increases with $k_b$, but only if the costs of innovation are not too small. When $\beta$ is sufficiently high, firms compete less on R&D and the investment levels would already be at lower levels. Yet we also know that increases in $k_b$ soften price competition, which implies that firms will increase their innovation levels.

Propositions 5 and 6 establish a qualitatively consistent pattern of results across monopoly and competitive conditions. In general, increases in $k_c$ and $k_b$ decrease the incentive to innovate when the economic value of the product is small and increase it otherwise. Underlying this robustness is a parallel between endogenous social comparison and positional rank ordered consumption (Frank 1985). In other words, social comparison related interactions endogenously create the positional consumption of different consumers. When the economic value of the product is relatively small, nonbuyers have the highest positional consumption on the social responsibility dimension because they create the least environmental damage. It is then that increases in social comparison effects reduce the incentive to innovate. Yet when the economic value is relatively high, then buyers of the innovation are likely to have the highest positional consumption. Here, increases in social costs and benefits increase the incentive to innovate. Interestingly, several examples of socially responsible innovations discussed in Section 1 come from mature product categories such as jeans or shoes where the potential for market expansion is low. The analysis predicts that as the social comparison preferences of consumers in these markets become more important, the incidence of socially responsible innovations should increase.

In the R&D game analyzed above, both firms launch the innovation when the R&D effort is successful. Because this leads to Bertrand competition, one can ask what happens if one of the firms could ex post withdraw the innovation that it launched and sell the basic product to be differentiated. Because the R&D game is simultaneous, each firm cannot observe if the rival also has the innovation when deciding whether to launch. Therefore, suppose that the firms have simultaneously launched the innovation. The question then is, does one of the firms have an ex post incentive to voluntarily withdraw its innovation? The practical reality is that such an action would almost surely involve product withdrawal costs. These costs could be both reputational and organizational. Our analysis can be seen as the case where these costs are significant. When the withdrawal costs are small, one of the firms might unilaterally withdraw its innovation. This eventuality is beset with an obvious coordination problem regarding which firm will withdraw.[16] Even if we ignore the coordination problems involved in such a product withdrawal game, the possibility of product withdrawal simply increases the expected payoffs to R&D investments for the firms compared to the analysis in Section 4. Consequently, the results pertaining to the effects of social comparison on innovation incentives are unaffected even if firms can ex post withdraw products.

### 4.1. Comparison of Innovation Incentives

We can compare the innovation investments under competition and monopoly for the basic case of symmetric social comparison effects. When the economic value of the product is low, competitive firms choose higher levels of innovation than a monopolist if the cost of innovation is sufficiently high. In these conditions, the absolute likelihood of innovation under competition is also higher as the probability of at least one firm having a successful R&D outcome under competition is $w^*(2-w^*)$ compared to $w^*$ under monopoly. This comes from the replacement effect, which stifles the monopolist's incentive to innovate. When the economic value of the product is low, the replacement effect for the monopolist is strong so investing is less attractive. Competitive firms do not encounter a replacement effect so their incentive to innovate is higher.

When the economic value of the product is high, the monopolist's replacement effect is weakened. The monopolist captures more value from innovation because buyers of the innovation do not face social comparison costs (there are few or no nonbuyers). In these conditions, the competitive effect is stronger than the replacement effect so the equilibrium level of innovation for a monopolist is higher than that chosen by a competitive firm.

In Section 4.2, we investigate the generality of the findings of this section by extending the analysis to a market where a potential innovator faces a perfectly competitive fringe that supplies the basic product.

### 4.2. Innovation When Facing a Perfectly Competitive Fringe

We examine how the existence of perfect competition in the product market affects the incentive of a firm to innovate. The innovating firm faces a perfectly competitive fringe that sells the basic product. Thus, if the firm's R&D efforts are successful, it competes with the fringe that offers the basic product at marginal cost. The consumer surplus functions will be as in (4), (5), and (6) but with the basic product price set at the competitive level $p_u = 0$. The following proposition compares the innovation investment levels with that of a monopoly. To do that, we define $L = 2(1+k_b) - k_c - \sqrt{(1-\delta)(1+k_b)(3(1+k_b)-4k_c)}$.

Proposition 7. *The equilibrium innovation level $w^*$ chosen by an innovator facing a competitive fringe is higher than that chosen by a pure monopolist when $2k_c < v < L$. Yet when $L < v < (1+k_b)$, the innovator facing a competitive fringe chooses $w^*$ that is lower than that chosen by the pure monopolist.*

The innovator facing a competitive fringe can have higher incentives to innovate than a pure monopolist that faces no product market competition. If the R&D of an innovator facing a fringe is unsuccessful then it competes with the fringe and its subgame profits are zero. By contrast, if the R&D is successful, then the innovator competes with basic products sold at marginal cost. This means that the firm's profit with the innovation is smaller than that of the pure monopolist. This highlights two opposing factors that affect the innovation incentives of a firm facing a fringe versus a

[16] The coordination problem arises because although both firms benefit if one of them unilaterally withdraws, the profits of the withdrawing firm are lower.

pure monopoly firm. When a firm faces a competitive fringe, there is zero replacement effect as no profits are earned when the firm's R&D is unsuccessful. By contrast, the pure monopolist faces a positive replacement effect, which affects the incremental profits of the innovation. Of course, when the innovator faces a competitive fringe, profits are reduced because of competition, unlike for the monopolist.

When $v$ is small, the negative competitive effect of the fringe is not very strong. At the same time, the replacement effect for a monopolist is substantial, which reduces the incentive to innovate. Thus, the pure monopolist has lower incentive to innovate. Moving to a situation where the economic value of the product is high, the situation is reversed. The adverse competition effect for a firm facing a competitive fringe is higher. Both the basic product and the innovation deliver the benefit $v$ and this is competed away by the fringe. By contrast, the benefit of a large $v$ is fully captured by a pure monopolist so her incentive to innovate is higher.

Note also that $\partial L/\partial \delta > 0$. More effective innovations reduce the feasible parameter region where the innovator facing a competitive fringe makes higher investments. This follows from the previous discussion about the countervailing replacement and competitive effects on innovation incentives. As $\delta$ drops, the relative importance of the replacement effect for the pure monopolist goes down and the incentive to invest increases. This implies that we are more likely to observe higher investments by a pure monopoly innovator when the effectiveness of an innovation is high.[17]

## 5. Discussion and Conclusion

Across a wide variety of markets, firms are investing in developing socially responsible products. This paper studies this incentive by linking the R&D decisions of firms to the interplay of the economic and social preferences of consumers. Consumers have social responsibility related preferences in addition to economic product utility from consumption. Preferences related to social responsibility have two distinct dimensions. They incur intrinsic costs to consume an environmentally inferior product and they also have endogenous social comparison preferences that come from their interactions with other consumers.

Social comparison effects have a nonmonotonic effect on the incentive to innovate and the pattern of these effects are consistent across monopoly and duopoly markets. When the economic value of the product is relatively low, increases in social comparison effects lead to lower levels of innovative activity. By contrast, when the economic value of the product is relatively high, increases in the social comparison effects lead to higher levels of innovative activity. The reversal in relationship is driven by how social comparison affects a firm's ability to capture the incremental value created by its innovation. The analysis also indicates that increases in social comparison costs are likely to induce firms to increase investments in socially responsible innovations in a wider range of markets than increases in social comparison benefits.

Social comparison benefits soften price competition, whereas social comparison costs intensify price competition. The model also provides insight about how a firm's incentive to innovate is affected as markets become more competitive. We find that when the economic value of a product is relatively low, competitive firms are likely to invest more in R&D than does a monopoly. Here, the monopolist's incentive to invest is reduced by the replacement effect, but competitive firms need the innovation to potentially create differentiation. By contrast, when the economic value of the product is high, the incentive to innovate is higher for the monopolist than for competitive firms. Now the replacement effect is small compared with the value created by the innovation, but greater innovation investments potentially create more competition.

By contrast to social comparison preferences, people sometimes derive in-group value from belonging to a category with others who are similar and consistent with their social identity (see Tajfel and Turner 1986, Hogg 2006 for reviews). We consider an extension where each consumer enjoys an in-group benefit when she encounters another who has made an identical consumption decision. As before, the social comparison effects emanate from interactions between consumers who have made different consumption decisions. Using the main model of Section 3, we assume that a consumer who purchases the innovation enjoys an expected in-group valuation of $g\tilde{t}$, whereas the consumer who refrains from buying has an expected in-group valuation of $g(1-\tilde{t})$ ($g$ is the strength of the in-group effect). The in-group valuations for the basic product can be represented analogously. The main results regarding the effect of the social comparison parameter ($k$) and the magnitude of the innovation ($\delta$) on the incentive to innovate are robust. Additionally, we find that the in-group effect can affect the incentive to innovate. When the impact of the innovation ($\delta$) is sufficiently high, increases in the in-group valuation $g$ raise the incentive to innovate. Conversely, when the impact of the innovation is not high, it is possible for the incentive to innovate to decrease with $g$.

[17] We also analyze a case of duopoly competition where the innovator faces competition from one firm that sells the basic product (as opposed to a competitive fringe). This reduces the intensity of competition yet the results are qualitatively consistent with those obtained for the competitive fringe. Because the intensity of price competition is lower here, the limit $L$ where the innovator (facing one competitor) invests more than the monopoly is higher.

This paper highlights the role of the interactions between nonbuyers and buyers in markets for socially responsible products. In a model where social comparison does not occur during nonbuyer/buyer interactions, we can show that the effect of social comparison is similar to that in the paper as long as the economic value of the product is sufficiently high.[18] However, increases in the strength of social comparison effects may increase innovation incentives even when economic value is small if the adverse effect of nonbuyer/buyer social comparisons is absent.

The broad message of our paper is that firms need to evaluate several factors when they engage in R&D to develop socially responsible products. Firms need to assess how salient social responsibility is for consumers in the category. They must also consider how public the consumption of the category is because it can affect the magnitude of the social comparison costs and benefits. Our analysis shows that socially responsible innovations are distinct from standard product innovations because nonbuyers influence the firm's ability to extract the surplus created by an innovation. Thus, we highlight the nuances of innovation and marketing strategy when improvements to products have social/environmental effects. These improvements are different than simple vertical improvements. Making a product better on the social/environment dimension is not the same as simply improving its quality. As the popularity of *green marketing* spreads to new categories, these differences need to be accounted for in the marketing strategies of firms.

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## Appendix

Proof of Lemma 1. The profit function of the monopoly with the innovation is $\pi_i = p_s \hat{t}_s$, where $\hat{t}_s = (v - p_s - \delta k)/\delta$ for partial coverage. The first-order conditions imply $p_s = (v - \delta k)/2$ and the equilibrium profits $\pi_i = (v - \delta k)^2/4\delta$. Note that if $v < \delta k$ the innovation cannot be sold at a positive price (but we assume that $v > k$ so that sales occur even for the basic product). The second-order condition is $\partial^2 \pi_i / \partial p_s^2 = -2/\delta < 0$. Substituting the price into $\hat{t}_s$ we obtain $t^* = (v - \delta k)/2\delta$. For $t^* < 1$ we have $v < \delta(2 + k)$. For full coverage, the monopoly innovator sets the price such that the consumer at $t = 1$ gets the surplus from the outside option of not buying. This implies that $p_s = v - \delta(1 + k)$ and so $\pi_i = v - \delta(1 + k)$. □

Proof of Proposition 1. When $k < v < \delta(2 + k)$, the first-stage expected profit function is $\Pi_i = w((v - \delta k)^2/4\delta) + (1 - w)((v - k)^2/4) - \beta w^2$. From this the equilibrium $w^* = (1 - \delta)(v^2 - \delta k^2)/(8\delta\beta)$. When $\delta(2 + k) < v < 2 + k$ the objective function for the innovator is $\Pi_i = w(v - \delta(1 + k)) + (1 - w)((v - k)^2/4) - \beta w^2$, which leads to the equilibrium innovation investment $w^* = ((v + k)^2 + 4(1 + k)(v + \delta))/(8\beta)$. From the above equilibrium outcomes the comparative statics in parts 1 and 2 of Proposition 1 follow. □

Proof of Lemma 2. The objective function of the pure monopoly with the innovation is $\pi_i = p_s \hat{t}_s$, where $\hat{t}_s = (v - p_s - \delta k_c)/(\delta(1 + k_b - k_c))$ under conditions of partial coverage. The first-order conditions imply $p_s = (v - \delta k_c)/2$ and the equilibrium profits $\pi_i = (v - \delta k_c)^2/(4\delta(1 + k_b - k_c))$. As before, we assume that the basic product can be sold ($v > k_c$). The second-order condition is $\partial^2 \pi_i / \partial p_s^2 = -2/(\delta(1 + k_b - k_c)) < 0$, which implies that $1 + k_b - k_c > 0$. Substituting the price into $\hat{t}_s$ we obtain $t^* = (v - \delta k_c)/(2\delta(1 + k_b - k_c))$. For partial coverage we require $t^* < 1$, which implies $v < \delta(2 + 2k_b - k_c)$. For full coverage, the monopoly innovator sets a price such that the consumer at $t = 1$ gets the surplus resulting from not buying. This implies that $p_s = v - \delta(1 + k_b)$ and so $\pi_i = v - \delta(1 + k_b)$. □

Proof of Proposition 2. When $k_c < v < \delta(2 + 2k_b - k_c)$, the objective function for the innovator is $\Pi_i = w((v - \delta k_c)^2/(4\delta(1 + k_b - k_c))) + (1 - w)((v - k_c)^2/(4(1 + k_b - k_c))) - \beta w^2$. From this the equilibrium $w^* = (1 - \delta)(v^2 - \delta k_c^2)/(8\delta\beta(1 + k_b - k_c))$. When $\delta(2 + 2k_b - k_c) < v < 2(1 + k_b) - k_c$ the objective function for the innovator is $\Pi_i = w(v - \delta(1 + k_b)) + (1 - w)((v - k_c)^2/(4(1 + k_b - k_c))) - \beta w^2$, which leads to $w^* = ((v + k_c)^2 + 4(1 + k_b)(v + \delta(1 + k_b - k_c)))/(8\beta(1 + k_b - k_c))$.

When $k_c < v < \delta(2 + 2k_b - k_c)$, $\partial w^*/\partial k_b = (-1/(8\beta\delta(1 + k_b - k_c)^2))(v^2 - \delta k_c^2)(1 - \delta) < 0$. Also $\partial w^*/\partial k_c = -(v^2 - 2\delta k_b k_c - 2\delta k_c + \delta k_c^2)(\delta - 1)/(8(1 + k_b - k_c)^2\beta\delta)$, which is negative when $v < \sqrt{\delta k_c(2 + 2k_b - k_c)}$ and positive otherwise. Furthermore, $\sqrt{\delta k_c(2 + 2k_b - k_c)} < \delta(2 + 2k_b - k_c)$, which establishes part 1 of Proposition 2. When $\delta(2 + 2k_b - k_c) < v < 2(1 + k_b) - k_c$, $\partial w^*/\partial k_c = (v - 2k_b + k_c - 2)(v - k_c)/(8(1 + k_b - k_c)^2\beta) > 0$ always. Furthermore, $\partial w^*/\partial k_b = (8\delta k_c - 2v k_c - 8\delta k_b - 4\delta + 8\delta k_b k_c + v^2 + k_c^2 - 4\delta k_b^2 - 4\delta k_c^2)/(8(1 + k_b - k_c)^2\beta)$. The numerator is negative when $v < k_c + 2\sqrt{\delta}(1 + k_b - k_c)$ and positive otherwise. These inequalities establish the comparative statics of parts 2 and 3 of Proposition 2. □

Proof of Proposition 3. Consider the main model with symmetric social comparison costs and benefits $k$. Let the marginal cost of the innovation be $c > 0$ and that of the basic product be zero as before. Suppose the firm with a successful R&D chooses to sell the product line consisting of both the innovation ($I$) and the basic product ($B$) and chooses prices $p_I$ and $p_B$, respectively. Consider that there are nonbuyers in equilibrium and partial coverage of the market. Using analysis similar to that in Section 4, given the prices, we can derive the rational consumer expectations of the marginal type between not buying and buying the innovation to be $\hat{t}_2 = (v - p_I - \delta k)/\delta$ and $\hat{t}_1 = ((p_I - p_B) - (1 - \delta)k)/(1 - \delta)$. The product line profit function of the firm will then be $\pi_{PL} = (p_I - c)(\hat{t}_2 - \hat{t}_1) + p_B \hat{t}_1$. From this the equilibrium prices can be calculated to be $p_I^* = \frac{1}{2}(v + c - \delta k)$, and $p_B^* = \frac{1}{2}(v - k)$ and consequently $t_2^* = (v - c - \delta k)/(2\delta)$ and $t_1^* = (c - k(1 - \delta))(2(1 - \delta))$. Note that $t_1^* > 0 \Rightarrow c > k(1 - \delta)$, $t_2^* < 1 \Rightarrow v < c + 2\delta(1 + k) - \delta k$, and $t_2^* > t_1^* \Rightarrow c < v(1 - \delta)$. We can also solve for the equilibrium

[18] Details of this analysis are available from the authors.

under full coverage with the product line in which case $t_2^* \to 1$, and the profit function being $\pi_{PL} = (p_I - c)(1-\hat{t}_1) + p_B\hat{t}_1$. The equilibrium prices can be derived to be $p_I^* = v - \delta(1+k)$, and $p_B^* = p_I^* - \frac{1}{2}(c + k(1-\delta))$ and this equilibrium can be shown to exist when $k(1-\delta) < c < (1+k)(1-\delta)$ and $v > c + \delta(2+k)$ (or else the market will not be fully covered).

Next, suppose that only the innovation is sold by the firm in which case $\pi_I = (p_I - c)\hat{t}$ and $\hat{t} = (v - \delta k - p_I)/\delta$. The equilibrium price is $p_I^* = \frac{1}{2}(v + c - \delta k)$ and for partial coverage the condition is $v < c + \delta(2+k)$, which is the same as the one in the case of the product line. When $v > c + 2\delta(1+k) - \delta k$, then there will be full coverage of the market when selling only the innovation and the equilibrium price $p_I = v - \delta(1+k)$. Note that the case where the firm only sold the basic product has already been analyzed previously. By comparing the single product profits we can show that the firm whose R&D is successful will always want to use the innovation $(\pi_I^* > \pi_B^*)$ if $c < (v + \sqrt{\delta}k)(1-\sqrt{\delta})$.

Comparing the equilibrium profits for the product line over the various ranges and the profits for the case of the innovation, we can derive the conditions in the proposition for the existence of the product line equilibrium. □

Proof of Proposition 4. The profit functions of the firm with the innovation and the basic product under partial coverage are $\pi_s = p_s(\hat{t}_2 - \hat{t}_1)$, $\pi_u = p_u\hat{t}_1$, where $\hat{t}_1 = ((p_s - p_u) - (1-\delta)k_c)/((1-\delta)(1+k_b-k_c))$ and $\hat{t}_2 = (v - p_s - \delta k_c)/(\delta(1+k_b-k_c))$. Substituting and taking the first-order conditions with respect to price and solving them simultaneously, we obtain $p_s^* = (2v - \delta k_c)(1-\delta)/(4-\delta)$ and $p_u^* = (v - 2k_c)\cdot(1-\delta)/(4-\delta)$. The marginal consumers between the basic product and the innovation and nonbuyers, respectively, are then $t_1^* = (v-2k_c)/((4-\delta)(1+k_b-k_c))$ and $t_2^* = ((2+\delta)v - 3\delta k_c)/(\delta(4-\delta)(1+k_b-k_c))$. From $t_1^*$ when $v < 2k_c$, there will be no demand for the basic product. Note that partial coverage implies $t_2^* < 1$ or $v < \delta((4-\delta)(1+k_b) - (1-\delta)k_c)/(2+\delta)$. Accordingly, when $2k_c < v < \delta((4-\delta)(1+k_b) - (1-\delta)k_c)/(2+\delta)$, the profits for the firm with the innovation and basic product, respectively, are $\pi_s^* = (1-\delta)(2v-\delta k_c)^2/(\delta(1+k_b-k_c)(4-\delta)^2)$ and $\pi_u^* = (1-\delta)(v-2k_c)^2/((1+k_b-k_c)(4-\delta)^2)$ and the comparative statics reported in part 1 of Proposition 4 follow.

When $\delta((4-\delta)(1+k_b) - (1-\delta)k_c)/(2+\delta) < v < (1+k_b)$, the objective functions of the firm with the innovation and the basic product will be $\pi_s = p_s(1-\hat{t}_1)$ and $\pi_u = p_u\hat{t}_1$.[19] The equilibrium prices are $p_s^* = (1-\delta)(2+2k_b-k_c)/3$ and $p_u^* = (1-\delta)(1+k_b-2k_c)/3$. The profits can be derived to be $\pi_s^* = (1-\delta)(2+2k_b-k_c)^2/(9(1+k_b-k_c))$ and $\pi_u^* = (1-\delta)(1+k_b-2k_c)^2/(9(1+k_b-k_c))$. The comparative statics reported in part 2 of Proposition 4 follow. □

### Innovation Under Competition

The objective function for the firms $i = 1, 2$ is $\Pi_i = w_i(1-w_j)\pi_s^* + w_j(1-w_i)\pi_u^* - \beta w_i^2$. Taking the first-order conditions with respect to the R&D decisions and simultaneously solving we obtain the symmetric equilibrium $w^* = w_1^* = w_2^* = \pi_s^*/(\pi_s^* + \pi_u^* + 2\beta)$. The $w^*$ obtains by substituting the relevant equilibrium profits from Proposition 4.

[19] Note that $v < 1 + k_b$ is necessary to ensure that the market is not fully covered with the basic product.

Proof of Proposition 5.

1. When $2k_c < v < \delta((4-\delta)\cdot(1+k_b) - (1-\delta)k_c)/(2+\delta)$, we can calculate $\partial w^*/\partial k_c$ and show that its sign is determined by the sign of the expression $v(1-\delta)\cdot(v-2k_c) + \beta(4-\delta)(2v - 2\delta - 2\delta k_b + \delta k_c)$. When $v > \delta(2+2k_b-k_c)/2$, then $\partial w^*/\partial k_c > 0$ because both terms are positive. When $v < \delta(2+2k_b-k_c)/2$ then $\partial w^*/\partial k_c < 0$ if $\beta > v(1-\delta)(v-2k_c)/((4-\delta)(\delta(2+2k_b-k_c)-2v))$. This proves part 1 of Proposition 5.
2. When $\delta((4-\delta)(1+k_b) - (1-\delta)k_c)/(2+\delta) < v < 1+k_b$, $\partial w^*/\partial k_c = (6(2+2k_b-k_c)(1-\delta)(2k_b - \delta - 2k_c + 3\beta k_c - 2\delta k_b + 2\delta k_c - 2k_bk_c + 2\delta k_bk_c + k_b^2 - \delta k_b^2 + 1))/(18\beta - 5\delta + 10k_b - 8k_c + 18\beta k_b - 18\beta k_c - 10\delta k_b + 8\delta k_c - 8k_bk_c + 8\delta k_bk_c + 5k_b^2 + 5k_c^2 - 5\delta k_b^2 - 5\delta k_c^2 + 5)^2$. The sign of $\partial w^*/\partial k_c$ is determined by $X_1 = 2k_b - \delta - k_c + 9\beta k_c - 2\delta k_b + \delta k_c - k_bk_c + \delta k_bk_c + k_b^2 - \delta k_b^2 + 1$. Rewrite $X_1$ as $9\beta k_c + (1-\delta)(k_b+1)(1+k_b-k_c) \Rightarrow X_1 > 0 \Rightarrow \partial w^*/\partial k_c > 0$. Therefore, we have that if $\delta(2+2k_b-k_c)/2 < v < 1+k_b$, then $\partial w^*/\partial k_c > 0$ proving part 2 of Proposition 5. □

Proof of Proposition 6.

1. When $2k_c < v < (4k_b - \delta - k_c - \delta k_b + \delta k_c + 4)\delta/(\delta+2)$, we can calculate $\partial w^*/\partial k_b$ and show that it is negative, which proves part 1.
2. When $(4k_b - \delta - k_c - \delta k_b + \delta k_c + 4)\delta/(\delta+2) < v < 1+k_b$, $\partial w^*/\partial k_b = -(6(2+2k_b-k_c)(1-\delta)(k_c - 6\beta - 6\beta k_b + 9\beta k_c - \delta k_c + k_bk_c - \delta k_bk_c - 2k_c^2 + 2\delta k_c^2))/(5\delta - 18\beta - 10k_b + 8k_c - 18\beta k_b + 18\beta k_c + 10\delta k_b - 8\delta k_c + 8k_bk_c - 8\delta k_bk_c - 5k_b^2 - 5k_c^2 + 5\delta k_b^2 + 5\delta k_c^2 - 5)^2$. The sign of $\partial w^*/\partial k_b$ is the opposite of $X_2 = k_c - 6\beta - 6\beta k_b + 9\beta k_c - \delta k_c + k_bk_c - \delta k_bk_c - 2k_c^2 + 2\delta k_c^2$. Rewrite $X_2$ as $k_c(1-\delta)(1+k_b-2k_c) - \beta(9k_c - 6k_b - 6)$. The coefficient of $\beta$ is $(9k_c - 6k_b - 6)$ and the term that does not depend on $\beta$ is $k_c(1-\delta)(1+k_b-2k_c)$. The sign of the coefficient of $\beta$ is negative if $k_c < \frac{2}{3}k_b + \frac{2}{3}$, which is always true because $k_c < \frac{1}{2}k_b + \frac{1}{2}$ for $p_u > 0$. As a result, $\partial w^*/\partial k_b > 0$ when $\beta > k_c(1-\delta)(1+k_b-2k_c)/(9k_c - 6k_b - 6)$ and this proves part 2 of Proposition 6. □

### Competitive Fringe Solution

The profit function of the innovator is $\pi_s = p_s(\hat{t}_2 - \hat{t}_1)$. Note that $p_u = 0$ in the case of the competitive fringe where $\hat{t}_1 = (p_s - k_c(1-\delta))//((1-\delta)(1+k_b-k_c))$ and $\hat{t}_2 = (v - \delta k_c - p_s)/(\delta(1+k_b-k_c))$. The equilibrium price can be calculated to be $p_s^* = ((1-\delta)/2)v$. Thus the equilibrium marginal consumers are $t_1^* = (v-2k_c)/(2+2k_b-2k_c)$ and $t_2^* = (v + \delta(v-2k_c))/(\delta(2+2k_b-2k_c))$. The expression for $t_1^*$ implies that $v > 2k_c$, is needed for the fringe product to have positive demand. Similarly, the expression for $t_2^*$ implies that when $v > 2(k_b+1)\delta/(1+\delta)$, all consumers in the market buy. Accordingly, when $2k_c < v < 2(k_b+1)\delta/(1+\delta)$, profits for the monopoly innovator are $\pi_s = v^2(1-\delta)/(4\delta(1+k_b-k_c))$. When $2(k_b+1)\delta/(1+\delta) < v < 1+k_b$, and there is full coverage, the objective function of the innovator is $\pi_s = p_s(1-\hat{t}_1)$ and from the first-order conditions on price we obtain $p_s^* = (1-\delta)(1+k_b)/2$. The profit is then obtained by substituting the equilibrium price. □

Proof of Proposition 7. The objective function for the innovator is $\pi_i = w\pi_s - \beta w^2$ (when the innovator is unsuccessful profits are zero when she competes with a competitive fringe). By using the relevant values of $\pi_s$ we obtain that when $2k_c < v < 2(k_b+1)\delta/(1+\delta)$, $w^* = (1-\delta)v^2/(8\delta\beta(1+k_b-k_c))$ and when $2(k_b+1)\delta/(1+\delta) < v < 1+k_b$, $w^* = (1-\delta)\cdot(1+k_b)^2/$

$(8\beta(1+k_b-k_c))$. When $2k_c < v < 2(k_b+1)\delta/(1+\delta)$, $w^*_{cf} = (1-\delta)v^2/(8\delta\beta(1+k_b-k_c))$ and $w^*_m = (1-\delta)(v^2-\delta k_c^2)/(8\delta\beta(1+k_b-k_c))$, denote, respectively, the innovation investments under the competitive fringe and the pure monopoly. Therefore, $w^*_{cf} - w^*_m = (1/(8(1+k_b-k_c)\beta))(1-\delta)k_c^2 > 0$. When $2(k_b+1)\delta/(1+\delta) < v < 1+k_b$, the monopolist facing a competitive fringe is in a situation of full market coverage, which implies that $w^*_{cf} = (1-\delta)(1+k_b)^2/(8\beta(1+k_b-k_c))$. When $v > \delta(2+2k_b-k_c)$, the pure monopoly innovator is also in a situation of full market coverage. Note that $\delta(2+2k_b-k_c) > 2(k_b+1)\delta/(1+\delta)$ unless $\delta < k_c/(2+2k_b-k_c)$. Assume that the situation is one of full coverage independent of whether the monopolist faces a competitive fringe or not. Then $w^*_m = ((v+k_c)^2 + 4(1+k_b)(v+\delta(1+k_b-k_c)))/(8\beta(1+k_b-k_c))$ and $w^*_{cf} - w^*_m = (3\delta - 4v + 2k_b - 4vk_b + 2vk_c + 6\delta k_b - 4\delta k_c - 4\delta k_b k_c + v^2 + k_b^2 + k_c^2 + 3\delta k_b^2 + 1)/(8(1+k_b-k_c)\beta)$. The numerator has two roots in $v$ but only the first root is less than the upper limit of the relevant zone. From this, when $v < L = 2(1+k_b) - k_c - \sqrt{(1-\delta)(k_b+1)(3(1+k_b)-4k_c)}$, $w^*_{cf} - w^*_m > 0$ and when not, $w^*_{cf} - w^*_m < 0$. The limit $L > \delta(2+2k_b-k_c)$ for all $\delta < 1$ (when $\delta = 1$ both sides of the inequality are equal). This implies that when $v > L$, $w^*_m > w^*_{cf}$ strictly. This proves Proposition 7. □

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