Social Responsibility and Product Innovation

Ganesh K. Iyer
University of California, Berkeley

David A. Soberman
University of Toronto[1]

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Abstract

In many markets, consumers care about consuming products that are socially responsible or environmentally friendly. We examine the incentives of firms to invest in product innovations that respond to social responsibility concerns. The paper connects the existence of the markets for socially responsible innovations to the presence of intrinsic and extrinsic social responsibility preferences. In addition to deriving economic value from the product, consumers have social responsibility preferences along two distinct dimensions. First, they have intrinsic costs for consuming a product which is socially/environmentally unfriendly and they are heterogeneous in these costs. Second, consumers also have social comparison preferences which are endogenous to the nature of their market interactions. They enjoy a social comparison benefit if their consumption decision is environmentally more responsible than the consumer that they meet in a social interaction. Conversely, they face the a social comparison cost if they meet someone whose consumption is more responsible.

The analysis reveals a robust result pertaining to innovation incentives across monopoly and competitive markets. When the economic value of the product is relatively small and there exist non-buyers in the market, the incentive to innovate decreases as social comparison costs and benefits increase. In contrast, when the economic value of the product is sufficiently large, increases in social comparison costs and benefits increase the incentive to innovate. Our analysis of competition also shows that social comparison benefits can act to soften price competition, while social comparison costs can exacerbate price competition. Finally, we identify market conditions where a monopoly invests more or less compared to a firm facing competition.

Keywords: social responsibility, R&D, innovation, environmental costs, sustainability, impure altruism, competitive strategy.

1　Introduction

Firms make significant investments to research and develop products that are socially responsible or less damaging to the environment. The Body Shop is well known for having created an enduring business model by investing in the development and promotion of products that eschew animal testing and by using environmentally friendly ingredients. Another example is effort of Lush Fresh Handmade Cosmetics that spent three years on R&D to develop a soap base that was not derived from palm oil.[1] Similarly, the decision at McCain to reformulate and market its entire lineup of products (more than 80 since 2010) to include only natural ingredients represented the biggest-ever undertaking for the company's research and development team (J. Wakana, "Big Food Companies Rush to Rejig Recipes," *Macleans*, May 19, 2012). In the automobile industry environmentally motivated product development relates not only to initiatives that reduce fuel consumption through alternative forms of propulsion (hybrid, electric, fuel-cell, and liquefied and compressed natural gas), but also efforts to replace plastic parts and foam (made from petrochemicals) with environmentally responsible alternatives (see "Green Wheels" April 2013, *The Economist*).

These commitments represent risky investments made by firms either to improve their demand or else to gain competitive advantage. But why should these investments matter for consumers over and above the economic utility that they get from the product? First, it may be that consumers have intrinsic concern for the negative impact of their consumption on the environment and the world they leave to future generations. This may lead them to expect responsible behavior from firms that would like to sell to them (Luo and Bhattacharya 2006). Around 90% of Fortune 500 companies reportedly engage in some form of corporate social responsibility (CSR) and several examples of product innovations related to CSR activities by leading firms are reported in Luo and Duo (2012). A second reason why socially responsible innovations matter is the nature of social interactions in product markets with social responsibility concerns. This is exemplified in the following quote from a recent article (see C. Sorensen, "Runaway Prius," *Macleans,* April 23, 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."

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[1] Palm oil production is considered to be one of the major causes of destruction of the habitat of the orangutan in Southeast Asia (K. Lunau, "Eco-Friendly Bottomlines," *Macleans,* May 7, 2012, p.42-47).

This highlights the potential social role that some environmentally responsible products play. Consumers may obtain extrinsic social utility by encountering others who do not drive a Prius. Of course, it also follows that consumers using environmentally damaging products may suffer a loss in social utility when they encounter those who consume environmentally superior products.

This idea while largely unexplored in the context of R&D investments, is related to several strands of research in both economics and social psychology. In economics, starting with Becker (1974) and then later Andreoni (1990), there is a body of research which considers the role of altruistic (intrinsic) versus social (extrinsic) concerns in the context of public goods and charitable donations. Andreoni's (1990) analysis of impure altruism highlights two factors that drive people's decisions to make donations: the intrinsic motivation (individuals have a pure altruistic motivation to donate) and the extrinsic motivation (individuals may be motivated by the social implications of their donations). In social psychology, starting with Festinger (1954), there is a stream of literature on social comparison wherein individuals compare themselves to others in order to make evaluations about themselves or about their consumption. Our model analyzes the interplay of intrinsic/altruistic consumer concerns about socially responsibility with the extrinsic social preferences in a product market setting where firms make investments in R&D.

We construct a model of a market in which consumers have social responsibility related preferences in addition to economic product utility. The social responsibility related preferences involve two distinct dimensions. First, consumers have intrinsic costs for consuming a environmentally inferior product and they are heterogenous in these costs. These costs can be seen as being analogous to altruistic concerns. Second, consumers also have social comparison preferences which are endogenous to the nature of their (random) social interactions with other consumers and to the R&D and pricing choices of firms. This can also be seen as endogenizing in a market setting the impure altruism motives of warm glow and cold prickle that have been highlighted in the context of charitable giving by Andreoni (1990). Specifically, consumers enjoy a social comparison benefit (warm glow) if they interact with others whose consumption involves greater social or environmental damage. Conversely, they may face the social comparison cost (cold prickle) if they interact with others whose consumption involve greater social responsibility.

Given this market setting, we consider the incentives, first of a monopolist and then those of competing firms to invest in innovation which makes their products environmentally responsible. Firm(s) first choose the level of the R&D investments and then follow by making pricing decisions. The investment level determines the probability with which the firm will obtain the innovation.

2

The innovation allows the firm to offer a product with reduced levels of the "social bad" (e.g., the extent of environmental damage) and the more effective the innovation, the greater is the reduction. Consumers therefore face lower levels of intrinsic costs depending upon the effectiveness of the innovation. The social comparison costs (benefits) that a consumer expects are dependent upon the extent to which her consumption is socially inferior (superior) in a social interaction, and upon 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 both social comparison costs and benefits adversely affects a monopoly innovator's profits. A monopolist would rather operate in a market where consumers did not have social comparison costs and did not value the social comparison benefits. Social comparison costs affect the willingness to pay of consumers who purchase the monopolist's product thereby affecting 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.

The manner by which social comparison costs and benefits affect the monopolist's incentive to innovate (i.e., the probability of innovation) is an important result of the analysis. The monopolist's incentive to innovate is determined by the incremental profit of the innovation which implies a replacement effect, in that a monopolist whose R&D is successful replaces her old product. How do the social comparison costs and benefits affect this incentive? When the economic value of the product is relatively low compared to the social preferences some consumers who are socially conscious do not buy. In this case, increases in both social comparison costs and benefits leads to lower equilibrium incremental profits from the innovation compared to the cost of innovating, leading to a decrease the incentive to innovate. However, when the relative economic value of the product is high compared to the social preferences, increases in the social comparison costs and benefits lead to higher incremental profits over and above the cost of innovating. As the relative economic value increases, even the more socially concerned consumers who have higher intrinsic costs decide to buy. This implies that the adverse effect of increases in the social comparison costs on the price a firm with the innovation charges is lower because of an interaction probability effect: i.e., increases in market coverage reduces the interaction probability that a consumer who purchases the product meets someone who has refrained from buying (which in this case is associated with superior socially responsible consumption). This probability effect on firm profits is even higher with the innovation than without and this increases the incentive to innovate. Similarly, when economic value of the product is sufficiently high and the market is fully covered, a firm with the

3

innovation is better able to counteract the adverse effect of the social comparison benefit enjoyed by potential non-buyers. This leads the firm to increase its innovation efforts.

We analyze the innovation incentives of a firm faced with a competitive fringe to highlight the role of product market competition. On the one hand, perfect competition in the product market can *increase* the incentive to innovate compared to the pure monopoly. For an innovating firm facing a competitive fringe the replacement effect is zero: i.e., the firm's profit in the absence of the innovation is zero and this increases the incentive to innovate. On the other hand, competition from the fringe reduces profits. When the economic value of the product is not too high compared to the social preferences the incentive to innovate of the firm facing the competitive fringe is higher. The analysis of duopoly competition in both R&D as well as in the product market leads to interesting results pertaining to price competition. Social comparison costs and benefits have distinct effects on price competition. While increases in social comparison benefits reduce price competition, increases in social comparison costs intensify price competition. In fact, one could say that social comparison benefits act to increase differentiation between products: even a firm that has just a basic product realizes profit increases under competition when social benefits experienced by consumers increase.

The result pertaining to the effects of social comparison costs and benefits on innovation incentives is remarkably consistent across monopoly and competitive markets. Specifically, when the economic value of the product is relatively low, then social comparison costs and benefits tend to have a negative effect on the incentive to innovate. In contrast, when the economic value of the product is relatively high then social comparison costs and benefits tend of have a positive effect on the incentive to innovate. The robustness of this result across market structures can be understood by linking our analysis of endogenous social comparison costs to the theory of positional consumption (Frank 1985). The argument runs as follows: When the economic value of the product is relatively small, then it is the non-buyers who have the highest positional consumption on the social responsibility dimension (i.e., they create the least environmental damage). It is then that increases in social comparison costs and benefits reduce the incentive to innovate. But when the economic value is relatively high, then it is the buyers of the innovation that will likely have the highest positional consumption. This implies that increases in social costs and benefits increase the innovation incentive. Thus, there is a link from our analysis of social comparison preferences to positional rank ordered consumption, except that the social comparison related interactions in our analysis endogenously create the positional consumption of different consumers.

Our analysis distinguishes socially responsible innovations from standard product innovations

by highlighting the role of the non-buyer on the appropriability of surplus and consequently the incentive to innovate. The existence of social comparison benefits and costs mutes the incentive to innovate when the economic value of the product is relatively small because an innovator is hit by both social comparison costs, which affect the buyer of the product when there are non-buyers, and social comparison benefits, which make not buying more attractive. When the economic value of the product is relatively high, the incentive to innovate is increased because an innovator is able to better appropriate the surplus from innovation. Now the effect of social comparison costs is to amplify the difference between a basic product and the innovation (with no non-buyers in the market, the buyer does not incur social comparison costs). In addition, when the economic value of the product is high, social comparison benefits reduce the attractiveness of the basic product even more than they reduce the attractiveness of the innovation.

1.1 Related Research

The classic article by Friedman (1970) argues that the responsibility of corporations is to maximize profits and shareholder welfare while conforming to the basic rules of the law and ethical custom. This view implies that personal altruism should play no role in the decision making of managers. There is also research which argues for the role of corporate social responsibility. This debate continues against the backdrop of an ever expanding number of companies that engage in charity or social causes (Vogel 2005). One rationale, according to some studies, is that 79% of consumers would switch to a brand associated with a good cause (see "Charity as Advertising: Give and Take," *The Economist*, February, 13, 2010, p.68).[2] Consistent with this, some of the empirical literature shows a general positive demand effect for socially responsible brands (e.g., Sen and Bhattacharya 2001). This suggests altruistic preferences on the part of consumers rather than managers as a basis to motivate responsible behavior on the part of firms. The framework in our paper is a characterization of this idea and it models how intrinsic/altruistic concerns of consumers as well as their social comparison preferences arising out of interactions with other consumers in the market affect firm decisions.

A paper by Baron (2001) examines strategic CSR by firms in response to the threat by an activist who seeks to re-distribute rents to an interest group. In this case, the firms use CSR as a strategy to maximize profits. Firms may also be disciplined by consumer activism; consumers boycott goods

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[2]Along these lines some papers analyze cause marketing (e.g., Krishna and Rajan 2009, Arora and Henderson 2007) or the incentives of firms to contribute to a cause because it is assumed that consumers are willing to pay a premium for a product which is associated with the cause.

which are perceived as socially irresponsible. John and Klein (2003) provide arguments based on psychological motivations such as self-esteem, guilt, and biased effectiveness evaluations for why consumers confronted by small-agent and free-riding problems still take costly acts to boycott firms. We explicitly consider the economic utility from buying a firm's product and consumers' intrinsic as well as their social comparison preferences which are endogenous to market outcomes. Thus, consumers may rationally choose not to buy the firm's product (i.e., boycott) if they deem the economic utility to be insufficient compared to the endogenous social costs of consumption.

Another stream of research has investigated social responsibility in markets which have the characteristics of both private goods and public goods. Research along these lines in the context of CSR include Bagnoli and Watts (2003) and Besley and Ghatak (2007). Our model is related to this literature; but we explicitly highlight the role of consumers' endogenous social comparison preferences in providing incentives to invest in risky innovations that reduce the environmental cost of the product. Further, the social comparison preferences and the intrinsic costs that predicate our analysis are likely to be more salient for product choice decisions in markets with large numbers of consumers, rather than the public goods rationale which is subject to consumer free-riding motivations (a consumer may be less affected by the social bad her consumption creates when there are a large number of others).

Some recent papers consider some strategic rationales for CSR. Banerjee and Wathieu (2013) examine the differential incentives of high and low quality firms to invest in CSR or to advertise in order to signal product quality and/or to improve market coverage. A recent paper by Branco and Villas-Boas (2012) considers competition between firms when they are required to follow a set of rules determined by law or by social practice and argues that greater competition may lead firms to invest less in following rules. This paper looks at the strategic R&D and innovation incentives of firms under monopoly and competition and how they are governed by the social preferences of consumers.

Our analysis is also related to research on the role of social interactions in markets for conspicuous goods or fashion goods. Amaldoss and Jain (2005) model firm's pricing decisions in markets with social interactions when some consumers have social value for exclusivity (their utility for a product decreases with the number of others who buy it) while others follow the bandwagon and have higher utility for a product when more people buy it.[3] Kuksov (2007) considers a different

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[3]Because social comparison effects considered in this paper are based on the number of users of different products, there is a relationship between our research and the literature on network externalities (Katz and Shapiro 1985).

type of social interaction in fashion goods where publicly consumed products play a matching role. A consumer may obtain a social benefit when she encounters another who consumes a similar product. A recent paper by Yoganarasimhan (2012) considers a model in which fashion acts as a social instrument through a matching/interaction game that helps individuals to both fit in with their peers as well as to differentiate themselves by signaling their taste. Our paper highlights a form of social interaction that is important for socially responsible products: i.e., an interaction where social benefits or costs for consumers arise out the positional role played by the products (Frank 1985). That is, consumers enjoy a social comparison benefit if they interact someone consuming a product that is inferior on the social responsibility dimension, while they incur a social comparison cost if they interact with someone who has a superior consumption on the social responsibility dimension.

Naturally, 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 and also the differential incentives of incumbents and entrants (see Dasgupta and Stiglitz 1982 and Gilbert and Newbury 1982). Our focus is on product innovations which reduce a social bad that concerns consumers and we investigate the incentives of both a monopoly as well as competitive firms to supply these innovations. Further, we are able to analyze how the magnitude of the social comparison costs and benefits and the relative economic utility of the product affects innovation incentives.

The rest of the paper proceeds as follows: The next section describes the model and in Section 3, we analyze the monopoly incentives to supply social innovation and compare it to that of a monopoly facing a competitive fringe. Section 4 examines how social responsibility preferences affect firms and their incentives to innovate when they compete in terms of both R&D and the product market. In Section 5 we compare the monopoly and competition cases and discuss some of the key points of the paper. Finally, Section 6 concludes.

2 Model

We begin by describing a market without the innovation. The firm has a basic product which provides an economic value v to consumers. The marginal cost of production is constant and is assumed to be zero without loss of generality. The consumption of each unit of the basic product is assumed to cause one unit of the social bad which can include, for example, the environmental costs of producing the product or any cost created by the consumer's product usage and consumption.

7

Consider now a firm that has an innovation which reduces the extent of the social bad/environmental damage that consumption of the product entails. We represent the degree to which the innovation is an improvement over the basic product by $\delta \in (0, 1)$ which represents the fraction of environmental damage created by new product. Thus an innovation with $\delta = 0$, completely eliminates the environmental damage associated with the basic product.

2.1 Consumer Preferences

We consider a unit market of consumers who make a choice about whether or not to purchase one unit of product given the price(s) that they observe. Note that every product (environmentally responsible or not) delivers an economic consumption value v to the consumer if purchased. In addition, consumers have social preferences which can result in social comparison costs and benefits.

Consumers exhibit social preferences along two distinct dimensions: First, consumers have intrinsic altruistic preferences which imply 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 the consumer with cost t also depends upon whether she is consuming the basic product or the one with the innovation: for the basic product the cost is t but for the innovation it is δt. Second, consumers have also have social comparison preferences which can imply benefits or costs. These benefits and costs are endogenous to the type of product that they consume as well as the nature of their social interaction with other consumers as specified below. Social comparison preferences are positional in nature and the consumer only incurs benefits or costs based upon whether her consumption is superior or inferior on the social responsibility dimension compared to that of the other consumer she meets in the social interaction. Further, 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 other consumers in the market.

Consider first social comparison costs. Let k_c denote the intensity of the social comparison costs. If a consumer buys the basic product (which creates one unit of environmental damage) and randomly encounters a consumer who does not buy the product (and so does not create any damage), she incurs a social comparison cost of k_c, whereas upon meeting a consumer with the innovation she incurs a social comparison cost of $k_c(1 - \delta)$. If the consumer were to buy the innovation she would still incur a cost of δk_c conditional on meeting a consumer who does not buy. Note therefore that the social comparison costs incurred by a consumer depend upon k_c and the

8

difference in the environmental damage created by her consumption and that of the other consumer in the interaction.

Consider next the social comparison benefits: let k_b denote the intensity of the social comparison benefit. If consumer buys the innovation (which creates δ units of environmental damage) and meets a consumer who buys the basic product she experiences a social comparison benefit of $k_b(1 - \delta)$. Similarly, if a consumer who chooses not to buy encounters another who buys the basic product, she obtains a social comparison benefit of k_b, whereas if she meets a consumer who buys the innovation she obtains a benefit of $k_b \delta$. Finally note that the costs and benefits specified above will be relevant for consumers depending upon the interaction probabilities of meeting other consumers in the social interaction. These probabilities will be endogenous to consumption choices and therefore endogenous to the R&D and pricing actions of the firms.

Note that in the above model construction, we posit that consumers are heterogenous in their intrinsic costs, but not on the social comparison dimensions. This represents the idea that social comparison needs may be specific to the product category characteristics. For example, Della Vigna et al. (2012) show that consumer decisions will be affected by external needs when the category is highly visible to other consumers. Note also that in the impure altruism framework of Andreoni (1990, 1995) the social comparison costs and benefits can be seen as being related (respectively) to the cold prickle and the warm glow effects. However, our model endogenizes these effects to social interactions that consumers have in the market and to firm decisions. Given that the warm glow and cold prickle effects in our model are social interactions based we can view the parameters k_c and k_b as representative of the degree to which the product category is consumed publicly.

2.2 Firm Decisions and Timing

In the first stage of the game, the firm makes an R&D decision w which is the success probability with which the firm realizes the innovation. If the firm has the innovation it will be able to sell a product which reduces the environmental damage by a fraction $\delta \in (0, 1)$. The cost of R&D is increasing and convex and given by $c(w) = \beta w^2$.[4] Note that in the case of duopoly competition the firms $j = 1, 2$ in the first stage simultaneously choose w_j. 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 the prices consumers form expectations of the demand and the probabilities of the relevant social interactions

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

and make their buying decisions. We solve for the sub-game perfect equilibrium of this game such that consumer expectations of demand are rational and consistent with the equilibrium.

3 Innovation Under Monopoly

We begin the analysis by constructing the consumer utility functions and the demand for a monopoly. After the first stage R&D decision, the firm will either be successful (s) or unsuccessful (u) and will choose contingent prices p_s or p_u in the second stage accordingly. Consider the case of the firm with the innovation charging a price p_s. A consumer of type (intrinsic cost) t who considers purchasing the innovation derives a surplus of:

$$CS_{sb} = v - \delta t - \delta k_c \left(1 - \tilde{t}\right) - p_s \tag{1}$$

The second term δt represents the intrinsic cost faced by the type t consumer when consuming the innovation: the innovation reduces the environmental damage by δ compared to the basic product. The third term represents the social comparison costs that are expected by the consumer. The consumers' 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 consumers' assessed probability of a random social interaction with a non-buyer.

Next, consider the surplus of a consumer that chooses not to buy (but who may encounter consumers that have purchased the monopolist's product):

$$CS_{s(nb)} = \delta k_b \tilde{t} \tag{2}$$

Notice that the non-buyer will meet a buyer with probability $\tilde{t}$ and enjoy a social comparison benefit. Because the innovation reduces the environmental damage by δ, the expected social benefit is equal to $\delta k_b \tilde{t}$. Consumer expectations in the third stage upon observing the firm's price p_s (and the product δ) must be rational. Therefore we can calculate the optimal demand as a function of firm decisions by equating (1) and (2), and then setting $t = \tilde{t} = \hat{t}_s$, to obtain $\hat{t}_s = \frac{v - p_s - \delta k_c}{\delta(1 + k_b - k_c)}$. Next, consider the case of a firm without the innovation which sells the basic product by charging a price of p_u. We can derive the relevant consumer surplus functions for the basic product by using $CS_{ub} = CS_{ub}(\delta = 1)$ and $CS_{u(nb)} = CS_{u(nb)}(\delta = 1)$. From this the optimal demand can be derived as a function of firm decisions for the basic product to be $\hat{t}_u = \frac{v - p_u - k_c}{(1 + k_b - k_c)}$.

Given the consumer decisions and demand as derived above, consider the firm actions and the equilibrium of the game. After the firm has chosen the investment w in the first stage, there are

10

two possible outcomes. If the R&D is successful the firm sells the innovation which reduces the environmental damage by δ, or if unsuccessful, it sells the basic product. If the R&D were to fail and the firm has only the basic product, we assume that it cannot sell to all consumers in the market. In other words, with the basic product some of the most socially conscious consumers (with high enough t) will choose not to buy the environmentally inferior basic product. This sets up the 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 $k_c < v < 2(1+k_b) - k_c$ (the lower bound is necessary for positive prices). The firm's profit in case when R&D fails is $\pi_u = p_u \hat{t}_u$. We can then calculate the second stage equilibrium profits of the monopolist without the innovation to be $\pi_u = \frac{(v-k_c)^2}{4(1+k_b-k_c)}$.[5]

Next, if the R&D is successful, we have more consumers with higher t's entering the market. Of course, if the innovation is sufficiently effective (i.e., low enough δ), or if v is sufficiently high, then all consumers buy the product ($\hat{t}_s = 1$) and the market will be fully covered. The firm's profit in the event 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 sub-game in which it has the innovation (the appendix shows the derivations).

Lemma 1 *For monopoly with an innovation of effectiveness δ, we have in equilibrium that:*

1. *If $v < \delta k_c$, then the innovation cannot be sold.*

2. *If $\delta k_c < v < \delta \left(2(1 + k_b) - k_c\right)$, then $t_s^* = \frac{v-\delta k_c}{2\delta(1+k_b-k_c)}$, $p_s^* = \frac{v-\delta k_c}{2}$ and $\pi_s^* = \frac{(v-\delta k_c)^2}{4\delta(1+k_b-k_c)}$.*

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

Firm profits are adversely affected by both k_c and k_b. Even with the innovation, a monopolist would rather operate in a market where consumers did not value social comparison benefits or did not incur social comparison costs. Social comparison costs affect the willingness to pay of consumers who purchase the monopolist's product and thereby constrain the price that the firm can charge. In contrast, social comparison benefits, adversely affect monopoly profits because they are enjoyed by consumers who refrain from buying.

The behavior of the equilibrium prices with respect to k_b and k_c reveal the strategic motivations of the monopolist innovator. Under partial coverage the equilibrium price charged goes down with k_c and is independent of k_b. When some of the most socially conscious consumers do not buy,

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[5]Throughout this section for the monopolist, with and without the innovation, the second order conditions for profit maximization imply that $1 + k_b - k_c > 0$.

an increase in social comparison costs (which affects the buyers) induces the firm to reduce price so as not to lose demand. However, suppose that the firm were to cut price in response to an increase in k_b. While the firm might increase demand, this comes with the disadvantage that it increases the interaction probability of a potential non-buyer with a buyer increasing the former's social comparison benefits. These two effects cancel out and the firm strategically finds it optimal to not change prices in response to an increase in k_b. *Intuitively, not responding with a price cut when faced with an increase in k_b is a way for the firm to strategically reduce the social comparison benefits of non-buyers by reducing the probability that non-buyers encounter a buyer.*

In contrast, when the economic value of the product is relatively high and all the consumers in the market buy the innovation, the equilibrium prices and profits are independent of k_c but decreasing in k_b. When all consumers buy, increases in k_c no longer affect firm prices because the probability that a buyer meets a non-buyer goes to zero. However, the marginal non-buyer at $t = 1$ now interacts with a buyer with probability one so increases in k_b reduce the price that the firm can charge.

We can now move to the first stage of the game and firm's R&D decision. The first stage expected profit function of the monopolist can be written as:

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

From this, the optimal incentive to innovate can be solved to be $w^* = \frac{\pi_s^* - \pi_u^*}{2\beta}$. The optimal incentive to innovate for the case of partial market coverage, when $\delta k_c < v < \delta(2(1 + k_b) - k_c)$, is calculated to be $w^* = \frac{(1-\delta)(v^2 - \delta k_c^2)}{8\delta\beta(1+k_b-k_c)}$. Under full coverage of the market when $v > \delta(2(1 + k_b) - k_c)$, the optimal levels of innovation is $w^* = \frac{(v+k_c)^2 + 4(1+k_b)(v+\delta(1+k_b-k_c))}{8\beta(1+k_b-k_c)}$.[6] Notice that 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 (i.e., when the R&D fails). This pertains to the replacement effect in that a monopolist innovator loses the profits associated with the basic product when the improved product is introduced. Thus, the magnitude of profits earned with the basic product affects the firm's incentive to innovate. We can therefore ask how this effect is governed by the social comparison costs and benefits in order to understand how they impact upon the incentive to innovate. This leads to the first proposition of the paper.

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[6] Note that when the firm's R&D activity is successful, it may also have the option to sell the basic product and the innovation. It can be shown that in this model, the monopolist does not have an incentive to offer a product line as long as the marginal costs are identical.

Proposition 1 *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 $\frac{\partial w^*}{\partial k_b} < 0$ and $\frac{\partial w^*}{\partial k_c} < 0$.*

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

3. *When $k_c + 2\sqrt{\delta}\left(1 + k_b - k_c\right) < v < 2(1 + k_b) - k_c$, then $\frac{\partial w^*}{\partial k_b} > 0$ and $\frac{\partial w^*}{\partial k_c} > 0$.[7]*

Overall, when the relative economic value of the product is sufficiently small, increases in social comparison costs and benefits decrease the monopolist's incentive to innovate. In contrast, when the economic value of the product is sufficiently large, they increase the incentive of the monopolist to innovate.

This proposition highlights a key insight of the paper. When the relative economic value is low, increases in k_c and k_b lead to lower equilibrium incremental benefits of innovating compared to the cost of innovating so the firm decreases w^*. As the relative economic value of the product increases, increases in k_b and k_c can lead to higher incremental benefits of innovation over and above the costs. To understand this, suppose then that the firm cuts price in response to an increase in the social comparison costs k_c. This would increase demand on the margin which positively affects the firm's profits. When the relative economic value to consumers is sufficiently high, more consumers with higher social concerns decide to buy (and the extent of market coverage is even higher with the innovation). This means that the probability with which a buyer meets a non-buyer drops. The reduction in the interaction probability of a buyer with non-buyers mutes the effect of increases in k_c on the expected social comparison cost; this occurs to an even larger extent when the firm has the innovation. In other words, increases in k_c have a lower negative effect on the price and demand when the firm has the innovation. Thus, in markets where the relative economic value of consumption is relatively high compared to the social preferences, increases in the social comparison costs of consumers can induce a monopolist to innovate with higher probability.

In a monopoly market, social comparison benefits k_b are enjoyed by non-buyers. Thus it is interesting that an increase in k_b can reduce the incentive of the firm to innovate. When the market coverage is partial or the economic value of the product not too high, recall from Lemma 1 that the monopolist strategically does not reduce price in response to increases in k_b. This

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[7]The right limit of the interval ensures that in the event the R&D is unsucessful, there is partial coverage for the firm with the basic product.

means that while an increase in k_b reduces the demand for the firm with the innovation relatively less than without the innovation, the benefit is not sufficient compared to the cost of innovating. Consequently, the incentive to innovate goes down with k_b. However, when the relative economic value of the product is sufficiently high, and in particular when the firm has the innovation and wants to fully cover the market, then increases in k_b increase the incentive to innovate. In such a case, the interaction probability of the non-buyer meeting a buyer is already one and the demand is inelastic. As a result, the relative reduction in the profits for the innovator for an increase in k_b is significantly lower compared to that for the basic product. Thus, the incentive to innovate increases with k_b.

Proposition 1 also provides an additional insight into the relative roles of k_b and k_c on the incentives of the innovator. Notice from parts 2 and 3 of the proposition that $\frac{\partial w^*}{\partial k_c}$ turns positive earlier in the range than $\frac{\partial w^*}{\partial k_b}$. In other words, there is a greater range of markets where increases in social comparison costs motivate firms to innovate rather than increases in social comparison benefits. The intuition turns on the fact that as coverage increases the effect of k_c is muted more quickly due to the reduction in the interaction probability between a buyer with a non-buyer. In contrast, as the relative economic value and coverage increases, the interaction probability between a non-buyer and a buyer is in fact higher which explains the increased effect of k_b on firm profits. This result has interesting implications: Exogenous shocks/events which highlight and accentuate social comparison costs of a product to the public may have a greater impact on motivating firms to invest in social innovation than events which highlight social comparison benefits of the product.

3.1 Innovation When Facing a Competitive Fringe

We now examine how the introducing (perfect) competition into the product market affects the incentive of the monopolist firm to innovate. Assume that the firm is facing a perfectly competitive fringe which sells the basic product. If one of the firms is a monopolist innovator and if its R&D is successful, then it will compete with the fringe selling the basic product at marginal cost. First, we consider partial coverage of the market and the market partitions as shown in Figure 1. The surplus associated with choosing the basic product at the competitive price $p_u = 0$ is:

$$CS_u = v - t_1 - k_c \left(1 - \tilde{t}_2\right) - k_c \left(1 - \delta\right) \left(\tilde{t}_2 - \tilde{t}_1\right) \tag{4}$$

The consumer surplus associated with choosing the innovation is:

$$CS_s = v - \delta t_2 - p_s + k_b(1 - \delta)\tilde{t}_1 - k_c \delta \left(1 - \tilde{t}_2\right) \tag{5}$$
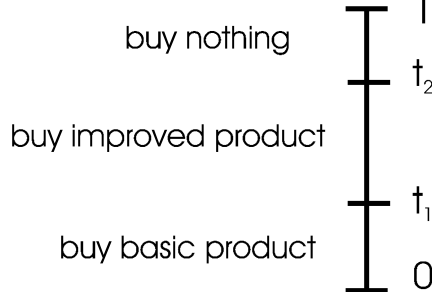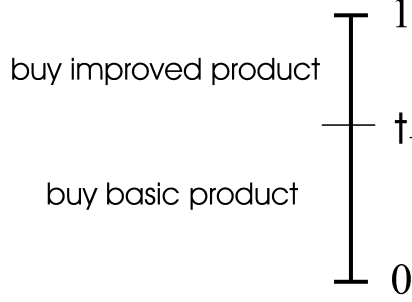
14

Figure 1: Competition with Partial Coverage

buy nothing

t_2

buy improved product

t_1

buy basic product

0

1

Figure 2: Competition with Full Coverage

buy improved product

t_1

buy basic product

0

1

Finally, the surplus associated with not buying is:

$$CS_{nb} = k_b \delta(\tilde{t}_2 - \tilde{t}_1) + k_b \tilde{t}_1 \tag{6}$$

The indifference condition for the marginal consumer t_2 between buying the innovation and not buying upon observing the prices is obtained by equating (5) and (6). Given rational consumer expectations, in equilibrium $t_2 = \tilde{t}_2 = \hat{t}_2$ and this implies that $\hat{t}_2 = \frac{v - p_s - \delta k_c}{\delta(1 + k_b - k_c)}$. Similarly by equating (5) and (4), we have that in equilibrium $t_1 = \tilde{t}_1 = \hat{t}_1$ and from this we derive $\hat{t}_1 = \frac{(p_s - (1-\delta)k_c}{(1-\delta)(1+k_b-k_c)}$. This implies that the second-stage profit function for the monopolist innovator is $\pi_s = (\hat{t}_2 - \hat{t}_1)p_s$.

In the analysis that follows, we focus on the cases where both the innovator and the fringe have positive sales in equilibrium, i.e., when $v > 2k_c$. Above this threshold for v, the market partition is as shown in Figure 1. Finally, when v is above a second threshold, the market partition is shown in Figure 2. Lemma 2 summarizes the market outcomes:

Lemma 2 *When the monopoly innovator facing the competitive fringe has the innovation the second stage equilibrium is as follows:*

1. *$2k_c < v < \frac{2(1+k_b)\delta}{1+\delta}$, then some consumers do not buy and $p_s^* = \frac{v(1-\delta)}{2}$ and $\pi_s^* = \frac{v^2(1-\delta)}{4\delta(1+k_b-k_c)}$.*

2. *$\frac{2(1+k_b)\delta}{1+\delta} < v < (1+k_b)$, then all consumers buy and $p_s^* = \frac{(1-\delta)(1+k_b)}{2}$ and $\pi_s^* = \frac{(1-\delta)(1+k_b)^2}{4(1+k_b-k_c)}$*

When the economic value of the product is not too large (part 1 of Lemma 2), increases in social comparison costs can increase the innovator's profits. This is different than the case of the pure monopolist in the previous section. Here, an increase in k_c can be a source of competitive advantage when the innovator competes with a fringe because it makes the basic product relatively less attractive. In this region, increases in k_b decrease the innovator's profits similar to the pure monopoly because it makes the option of not buying more attractive.

In the range $\frac{2(k_b+1)\delta}{1+\delta} < v < 1 + k_b$, the comparative statics for both social costs and benefits are positive: $\frac{\partial \pi_i}{\partial k_c} > 0$ and $\frac{\partial \pi_i}{\partial k_b} > 0$. In contrast to the case of the pure monopoly, as the economic benefit of the product becomes relatively high and the market is fully covered, social comparison costs continue to have a positive effect on the innovator's profit because of greater interaction probability that the consumer with the basic product encounters consumers who purchased the innovation. Further, increases in k_b have a positive effect on the innovator's profit. This effect is unlike the case of the pure monopoly where social comparison benefits are always enjoyed by the non-buyers and therefore adversely affect the monopolist's profits. Here, the innovator faces a competitive fringe so increases in k_b can have a positive effect on profits because of the benefit that consumers with the innovation obtain when they interact with consumers of the basic product.

In the following proposition, we consider the R&D decision and compare the innovation investments levels with that of the pure monopoly innovator. 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 2 *The equilibrium innovation level w^* chosen by an innovator facing a competitive fringe is higher than that chosen by a pure monopolist when $2k_c < v < L$. But 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 develop the innovation compared to a pure monopolist that faces no product market competition. If a firm's R&D is unsuccessful then it will be in perfect competition with the fringe and its profits in the sub-game will be zero. In contrast, if the R&D is successful, then the innovator will compete with the basic product offered by the fringe which implies that the firm's profit with the innovation is smaller than that of the pure monopolist. This indicates the opposing forces that govern the incentives of the firm when facing a fringe as compared to a pure monopoly firm.

For the pure monopoly, the incentive turns on how much of an increase in profits the innovation

delivers compared to the pre-innovation profits. For the pure monopolist, the pre-innovation profits are effectively lost with the new innovation is introduced, i.e., the replacement effect. When the monopolist faces a competitive fringe, the lost profit is due to competition. For the pure monopolist, the replacement effect (which drives innovation levels down) is stronger, whereas for the innovator facing the competitive fringe the competitive effect is obviously stronger.

The innovator facing a competitive fringe has a higher incentive to innovate when the economic value of the product is low, whereas the pure monopolist has higher incentives to innovate when the economic value of the product is sufficiently large. When v becomes large the adverse competitive effect is substantial. Both the basic product and the innovation deliver the benefit v and this is competed away when there is a competitive fringe. In contrast, the benefit of a large v, is fully captured by a pure monopolist. When v is small the competitive fringe does not induce too much of an adverse effect, where as the replacement effect for the pure monopolist is substantial.

Note also that $\frac{\partial L}{\partial \delta} > 0$. 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 δ 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.

For completeness, we also considered a case of duopoly competition in the product market where the innovator faces competition from only one firm offering the basic product (as opposed to a competitive fringe). This reduces the intensity of competition across all conditions yet the analysis yields results that are qualitatively consistent with results obtained for the competitive fringe. Because the intensity of price competition is lower in the duopoly case when the innovator faces only one firm with the basic product rather than the competitive fringe, the innovation incentives for the duopoly case would dominate that for the pure monopolist over a smaller set of market conditions (i.e., the corresponding limit L would be higher).

3.2 Innovation Under Duopoly Competition

We now move the case of duopoly competition between firms in both R&D and prices. In the first stage, firms simultaneously choose their R&D investments w_i ($i = 1, 2$) which then leads to one of the three types of outcomes that firms face in the pricing sub-game. If the R&D of both firms is unsuccessful, then they both compete with the basic product, and if both firms' R&D is successful

they both have the innovation in stage 2. In both of these cases, firms compete with identical products leading to zero profits in the sub-game.[8] Finally, when only one firm has the innovation (only its R&D was successful), the firms compete with differentiated products.

The consumer surplus functions in the case of differentiated competition between the firm with the innovation and the firm with the basic product can be written as follows (as before the subscripts s and u denote the innovation and the basic product respectively):

$$CS_s = v - \delta t_2 - p_s + k_b(1-\delta)\tilde{t}_1 - k_c\delta\left(1 - \tilde{t}_2\right) \tag{7}$$

$$CS_u = v - t_1 - p_u - k_c\left(1 - \tilde{t}_2\right) - k_c\left(1 - \delta\right)\left(\tilde{t}_2 - \tilde{t}_1\right) \tag{8}$$

$$CS_{nb} = k_b\delta(\tilde{t}_2 - \tilde{t}_1) + k_b\tilde{t}_1 \tag{9}$$

where (7) is the surplus of the consumer at t_2 from buying the innovation and (8) is the surplus of the consumer at t_1 from buying the basic product. Finally, (9) is the utility of the consumer who chooses not to buy.

The indifference condition for the marginal consumer t_2 between buying the innovation and not buying upon observing the prices is obtained by equating (7) and (9). Given rational consumer expectations, it should be the case that in equilibrium $t_2 = \tilde{t}_2 = \hat{t}_2$ and so we derive that $\hat{t}_2 = \frac{v-p_s-\delta k_c}{\delta(1+k_b-k_c)}$. Similarly by equating (7) and (8), we have that in equilibrium $t_1 = \tilde{t}_1 = \hat{t}_1$ and from this we can derive $\hat{t}_1 = \frac{(p_s-p_u)-(1-\delta)k_c}{(1-\delta)(1+k_b-k_c)}$. This implies that the second-stage profit functions for the two firms in this case of partial coverage are $\pi_s = (\hat{t}_2 - \hat{t}_1)p_s$ and $\pi_u = \hat{t}_1 p_u$. We analyze the case where both firms compete with positive demand which requires that $\hat{t}_1 > 0$ or $v > 2k_c$. In the case of full coverage, $CS_s > CS_{nb}$ for all $t < 1$ so $t_2 = 1$. Here, the profit functions of the firms are $\pi_s = (1 - \hat{t}_1)p_s$ and $\pi_u = \hat{t}_1 p_u$. We now solve for the second-stage (post R&D) sub-game pricing equilibrium when one firm has the innovation but the other does not and this leads to Proposition 3.

Proposition 3 *When the one firm has the innovation, but the other firm has the basic product, the second stage equilibrium implies the following:*

1. *When $2k_c < v < \frac{\delta((4-\delta)(1+k_b)-(1-\delta)k_c)}{2+\delta}$, then the market under competition is not fully covered. In this case, the profits of the firm with the innovation and the firm with the basic product decrease with increases in k_b and k_c.*

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[8] When both firms have the innovation, it might be asked, can one of the firms voluntarily withdraw its innovation and sell the basic product in order to increase profits? At the end of this section, we discuss the implication of allowing one of the firms to withdraw its innovation.

2. When $\frac{\delta((4-\delta)(1+k_b)-(1-\delta)k_c)}{2+\delta} < v < (1+k_b)$, then the market under competition is fully covered. In this case the profits of the firm with the innovation increases with increases in both k_c and k_b. In contrast, the profits of the firm with the basic product decreases with k_c but increases with k_b.

3. Finally, profits of both firms decrease as δ increases.

This proposition characterizes the equilibrium of the differentiated pricing competition between a firm with the innovation and a firm with the basic product. The first part of Proposition 3 considers the case in which the economic value of the product is sufficiently low such that some of the consumers who have high intrinsic costs refrain from entering the market. Increases in both the social comparison costs and benefits now reduce the equilibrium profits of the firms. This result is qualitatively similar to the finding in the case of the monopoly.

To understand this result it is useful to analyze how k_c and k_b affect the prices and demand of the firms. The equilibrium prices are $p_s^* = \frac{(1-\delta)(2v-\delta k_c)}{4-\delta}$ and $p_u^* = \frac{(1-\delta)(v-2k_c)}{4-\delta}$. Prices of both firms go down with k_c. In other words, increases in social comparison costs act to intensify price competition. The firm with the basic product responds by reducing price for two reasons. Reducing price allows the firm to recoup the demand that may be lost to the innovation. Second, increases in demand reduce the interaction probability between a consumer of the basic product and those who either purchased the innovation or who did not buy at all. As a result, increases in k_c reduce p_u and then because prices are strategic complements under competition, the firm with the innovation also responds by reducing its price p_s.

When the economic value of the product is relatively low, firms' prices do not respond at all to increases in k_b. To understand this let us start with the firm selling the basic product. An increase in k_b is unequivocally negative for this firm's demand under competition because consumers of the basic product have purchased a product that is environmentally inferior. Cutting price in response to an increase in k_b might help the firm with the basic product to increase demand at the margin, but it also comes with the disadvantage that an increase in demand generates an adverse interaction effect. That is, higher demand increases the likelihood that consumers of the innovation and the non-buyers encounter a consumer of the basic product and the social comparison benefit increases with k_b. This later effect nullifies the demand effect of the price cut and thus, the incentive of the firm with the basic product to reduce price. Increasing the price in response to an increase in k_b is not optimal either as it will reduce demand even further.

19

What about the firm with the innovation? If it increases its price in response to an increase in k_b it could increase its margin, yet not lose consumers to the firm with the basic product. But an increase in k_b also increases the social benefit of not buying. As a result, if the firm with the innovation increases price it loses demand on the no purchase margin. These two effects cancel out. Conversely, suppose that the firm with the innovation were to reduce price. This will increase its demand on the margin with basic product and on the non buying margin as well but this is nullified by increased interaction probability for the non-buyer which increases the appeal of not buying. That is, a non-buyer will enjoy a greater social comparison benefit, the higher is the demand for the innovation. In sum, a series of countervailing effects leads to both firms strategically choosing not to respond in price to increases in k_b.

We can now explain the behavior of profits with respect to the social comparison costs and benefits when the market is not fully covered. Profits of both firms go down as k_b and k_c increase. Note from the discussion above that increases in social comparison costs intensify price competition resulting in lower profits for both firms. An increase in k_b also reduces the equilibrium profits of both firms, albeit through a somewhat different mechanism. Note that firms do not respond strategically through their prices when social comparison benefits increase. The presence of non-buyers nullifies the effects of price reductions in response to increases in k_b for the firms. Increases in social comparison benefits cause the option of not buying to be more attractive, constraining the demand of both firms (especially when v is small). Consequently, when the economic value of the product relative to the social preferences is relatively low, increases in both social comparison costs and benefits reduce the equilibrium profits of the firms.

Part 2 of the Proposition describes the equilibrium when the relative economic value of the product is sufficiently high. Comparing the equilibrium to the previous case helps to highlight some important economic characteristics of competition in markets with social responsibility concerns. Here, the nature of the equilibrium is qualitatively different. Higher social comparison costs confer a competitive advantage to the firm with the innovation. Profits of the firm with the innovation increase with k_c and the profits of the basic product are adversely affected. In contrast, increases in social comparison benefits increase the profits of both competing firms.

To understand the intuition, it is once again useful to analyze the behavior of the equilibrium prices which can be derived for this case to be $p_s^* = \frac{(1-\delta)(2+2k_b-k_c)}{3}$ and $p_u^* = \frac{(1-\delta)(1+k_b-2k_c)}{3}$. Notice that the prices of both firms go down in response to an increase in k_c. An increase in social comparison costs places a negative effect on the basic product which then reduces the price

it charges. The strategic complementarity of prices then induces the firm with the innovation to also reduce its price (but to a lesser extent). Thus, as in part 1 of the proposition, increases in k_c intensify price competition between the firms. We can also show that the resulting 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), while that of the firm with the basic product decreases. Consequently, increases in k_c create a competitive advantage for the firm with the innovation despite intensified price competition: the profits of the firm with the innovation increases.

Consider now the comparative statics with respect to social comparison benefits. As k_b increases, the firm with the innovation faces only a positive externality because all consumers buy in equilibrium. Thus, the price charged by the firm with the innovation increases with k_b and through the strategic complementarity of prices, this induces the firm with the basic product to also increase its price. Thus, an increase in social comparison benefits acts to soften the intensity of price competition and increases the profits of both firms. Recall, non-buyers exert a negative externality on firms through the price by forcing the firm with the innovation to reduce price. When the relative economic value of the product is high enough, the negative externality placed by non buyers on the firms is reduced. 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, unlike in the case of the monopoly, social comparison benefits can be a "good" for firms under differentiated competition because they tend to strategically mitigate price competition. Further, though social comparison costs exacerbate price competition, they can also be source of competitive advantage for a firm with the innovation. We end the discussion of Proposition 3 by noting as in part 3, that the equilibrium profits decrease with δ for both the firms. A decrease in δ implies that the innovation is more impactful so it is natural that the profits of the firm with the innovation should increase. But the profits of the firm with the basic product increase too. And this is because δ is also a measure of the extent of differentiation between the firms; smaller values imply that the two competing products are more differentiated.

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

$$\Pi_i = w_i(1 - w_{-i})\pi_s + (1 - w_i)w_{-i}\pi_u - \beta w_i^2 \tag{10}$$

The symmetric Nash equilibrium of the first stage game in R&D investments can then be solved for

21

the equilibrium innovation incentive $w_i^* = \frac{\pi_s}{\pi_s + \pi_u + 2\beta}$.[9] The incentive to innovate under differentiated competition is a function of how large the innovation profits are compared to the total profits earned by both firms. In addition, notice that even if the innovation were to be costless ($\beta = 0$) competitive firms in a symmetric equilibrium do not innovate with probability one.

In the propositions that follow, we describe the effects of the social comparison parameters on the incentive to innovate under competition. We start with k_c.

Proposition 4 *The comparative statics for the level of innovation w^* with respect to k_c are as follows:*

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

2. *When $\frac{\delta(1+k_b) - k_c}{2} < v < (1 + k_b)$, then w^* is increasing in k_c.*

Social comparison costs tend to have a negative effect on the incentive to innovate under competition when the economic value of the product is not too high and the market is not fully covered. This is especially the case when the cost of innovating is sufficiently high. In this case, a firm contemplating the correct amount of R&D effort to exert, contends with the fact the potential non-buyers of the product place a negative externality on the buyers (and therefore on the firm). This negative externality increases with k_c. Thus, the incentive to innovate decreases.

In contrast, when the economic value of the product increases and all consumers buy, the negative externality placed by the potential non-buyers decreases. Now increases in k_c is a "good" for the firm if it has the innovation and a "bad" if it does not. Consequently, as shown in part 2 of the proposition the equilibrium innovation level increases with k_c. The final proposition of the paper presents the effect of k_b on the innovation incentives under competition.

Proposition 5 *The comparative statics for the level of innovation w^* with respect to k_b are as follows:*

1. *When $2k_c < v < \frac{\delta((4-\delta)(1+k_b) - (1-\delta)k_c)}{2+\delta}$, then w^* is decreasing in k_b.*

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[9]For completeness, we should note that if β is sufficiently small, there may exist asymmetric equilibria in which one firm invests to obtain the innovation with certainty, while the other chooses not to invest at all. However, the threshold of costs below which the asymmetric equilibria can occur is less than the minimum threshold of β required in Section 2.2 to avoid the degenerate case that the monopoly innovator invests to obtain the innovation with certainty.

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

Proposition 5 confirms a consistent pattern of results that we uncover across different market structures in this paper. As the economic value of the product increases in relation to social preferences, the impact of k_b moves from having a negative effect on the incentive to innovate to having a positive effect. The proposition also highlights some new effects pertaining to innovation incentives under competition. When the economic value of the product is sufficiently large, the incentive to innovate w^* increases with k_b, but only if the costs of innovation are not too small. This reveals the interplay of competitive innovation with social comparison preferences. When the costs of innovation are sufficiently large firms compete less on R&D. But we also know that increases in k_b help to soften price competition, which implies that firms can afford to increase their innovation levels.

Overall, the effect of social comparison costs and benefits on the incentive to innovate is robust across monopoly and competitive market structures: 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 connection between our analysis of endogenous social comparison costs and the theory of positional consumption (Frank 1985). When the economic value of the product is relatively small, it is the non-buyers who have the highest positional consumption on the social responsibility dimension as they create the least environmental damage. It is then that increases in social comparison costs and benefits reduce the incentive to innovate. But when the economic value is relatively high, it is the buyers of the innovation that have the highest positional consumption. Now increases in social costs and benefits increase the innovation incentive. Our analysis of social comparison preferences can therefore be linked to the theory of positional rank ordered consumption, in that social comparison related interactions endogenously create the positional consumption of different consumers.

The above discussion also points to an interesting characteristic of markets where social comparison effects are important: i.e., the role of the non-buyer. The realization that non-buyers are just as important as buyers for understanding markets for social responsibility is a new insight, but it is being increasingly acknowledged by practitioners (see Smith "To Buy or Not to Buy," *Marketing News*, 2013, 47(9), p. 117). In most product markets, it is by not consuming that consumers place no cost on the environment. As a result, the non-buyer derives a social comparison benefit from interactions with consumers consuming a product of any kind. This constrains the price that can

be charged for either a basic product or an innovation.

A useful perspective for the result on the incentive to innovate can also be had by connecting the role of the non-buyer to the effect of appropriability of surplus on innovation incentives. As noted by Hirschleifer (1971), under-investment in inventive activity is affected by an innovator's ability to appropriate the value created by the innovation. In this paper, the existence of social comparison benefits and costs mutes the incentive to innovate when the economic value of the product is relatively small. Why? Because an innovator is hit by both social comparison costs, which affect the buyer of the product when there are non-buyers in the market, and social comparison benefits, which make not buying more attractive. When the economic value of the product is relatively high, the incentive to innovate increases with social comparison costs and benefits because an innovator is able to appropriate greater surplus from the innovation. Now the only effect of social comparison costs is to amplify the difference between a basic product and the innovation (with no non-buyers in the market, the buyer does not incur social comparison costs). In addition, when the economic value of the product is high, social comparison benefits reduce the attractiveness of the basic product more than they reduce the attractiveness of the innovation.

Note that similar to the case of the monopoly, we also obtain the qualitative result in competitive conditions that increases in k_b lead to higher levels of innovation for a narrower range of market conditions than for increases in k_c. Here, this finding comes from the way that k_b affects firms in asymmetric conditions where one firm has the innovation but the other does not. Because increases in k_b tend to i) relax price competition and ii) have positive effects on the profits of the firm with the innovation as well as the firm with the basic product, increases in k_b narrow the gap between the profits of the two firms in the asymmetric condition. Recall that the incentive to innovate under competition is a function of the ratio of the profit with the innovation to industry profit in asymmetric conditions. So a smaller gap between the profits with and without the innovation reduces the incentive to innovate. As long as the conditions entail partial market coverage, this gap becomes smaller with increases in k_b and so $\frac{\partial w^*}{\partial k_b} < 0$ across a wider range of market conditions. Thus we once again have the somewhat unusual finding that an increase in the social comparison cost, k_c, is likely to spur innovation in a wider range of market conditions than an increase in the social comparison benefit, k_b. Oddly, changes in a parameter which reduces competition and makes both players in the market better off is more likely to reduce innovative activity.

In the R&D game analyzed above, both firms launch the innovation when the R&D programs are successful. However, because this leads to Bertrand competition and zero profits, it might be

useful to ask what would happen if one of the firms could withdraw the innovation and use only the basic product so as to be differentiated. Because the R&D game is simultaneous, in the first stage each firm does not observe if the rival also has the innovation when deciding whether to launch the innovation. Therefore, suppose that the firms have simultaneously launched the innovation. An interesting question is, does one of the firms have an incentive to voluntarily withdraw its innovation? In reality, such an action might involve product withdrawal costs. These withdrawal costs might arise from reputational costs imposed by consumers who punish firms in the future for withdrawing an environmentally superior product. The analysis of this paper can then be seen as the case in which these costs are prohibitively high. When the withdrawal costs are small, it is conceivable that one of the firms might unilaterally withdraw its innovation. Not withstanding the coordination problems that are involved in such a product withdrawal game, the possibility of product withdrawal simply increases the expected payoffs to R&D investments for the firms as compared to the analysis in the paper.[10] Accordingly, our results pertaining to the effects of k_b and k_c on the equilibrium innovation incentives are unaffected even if firms can ex-post withdraw products.

4   Conclusion

This paper studies the incentive of firms to invest in socially responsible innovations by linking the R&D decisions of firms to the interplay of the economic and social motivations in the consumer market. Consumers have social responsibility related preferences in addition to economic product utility from consumption. Social responsibility related preferences in this paper have two distinct dimensions: First, consumers have intrinsic costs for consuming a environmentally inferior product; this is analogous to altruistic concerns. Second, consumers have endogenous social comparison preferences that come from their interactions with other consumers.

Social comparison costs and benefits can either *increase or decrease* the incentive to innovate. When the economic benefit provided by a product is low in relation to the social responsibility preferences, increases in the social comparison costs lead to lower levels of innovative activity. In contrast, when the economic benefit provided by a product is high in relation to the social comparison costs, increase in the social comparison costs lead to higher levels of innovative activity. When the relative economic value is high, even socially concerned consumers with high intrinsic

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

costs decide to buy and market coverage is fuller. Here, increases in social comparison costs and benefits lead to higher levels of innovation. This reversal in relationship is largely driven by the innovator's ability to appropriate the surplus created by the innovation. When the relative economic value is high, innovator's ability to appropriate the value created by the innovation is higher. This finding is robust across monopoly and competitive conditions. Further, the incentive to innovate increases in response to increases in social comparison costs for a wider range of conditions than is the case with increases in social comparison benefits. This means that increases in social comparison costs are more likely to induce firms to increase investments in socially responsibility than increases in social comparison benefits.

The model clarifies how the incentive for innovation is affected by the introduction of competition in the product market. Perfect competition in the product market can *increase* the incentive to innovate compared to a pure monopoly when the economic value of the product is not too large. Finally, the analysis of duopoly competition in terms of *both* R&D activity and subsequently in the product market highlights a striking difference in the effects of social comparison costs and benefits on price competition. In particular, social comparison benefits tend to relax price competition and social comparison costs tend to intensify price competition.

The paper argues that firms need to assess several factors when they engage in R&D activity to develop products that are better for the environment. First, they need to assess how salient the environmental costs are for consumers. Second, they need to assess how public the consumption of the category is, as it may affect the magnitude of the social comparison costs and benefits. More importantly, our analysis shows that socially responsible innovations are distinct from standard product innovations in that the role of the non-buyers is critical as they affect the firm's ability to appropriate the surplus created by an innovation. Thus our paper highlights 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 accounted for in the marketing strategies of firms.

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Appendix

Proof of Lemma 1

The objective function of the pure monopoly with the innovation is $\pi_i = p_s \hat{t}_s$ where $\hat{t}_s = \frac{v - p_s - \delta k_c}{\delta(1 + k_b - k_c)}$ under conditions of partial coverage. The first order conditions imply $p_s = \frac{v - \delta k_c}{2}$ and the equilibrium profits $\pi_i = \frac{(v - \delta k_c)^2}{4\delta(1 + k_b - k_c)}$. Notice that if $v < \delta k_c$ the innovation cannot be sold at a positive price. The second order condition is $\frac{\partial^2 \pi_i}{\partial p_s^2} = -\frac{2}{\delta(1 + k_b - k_c)} < 0$ which implies that $1 + k_b - k_c > 0$. Substituting the price into $\hat{t}_s$ we obtain $t^* = \frac{v - \delta k_c}{2\delta(1 + k_b - k_c)}$. For partial coverage we require $t^* < 1$ which implies $v < \delta(2 + 2k_b - k_c)$. For full coverage, the monopoly innovator sets 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 $\pi_i = v - \delta(1 + k_b)$. $\square$

Proof of Proposition 1

When $k_c < v < \delta(2 + 2k_b - k_c)$, the objective function for the innovator is

$$\pi_i = w \left(\frac{(v - \delta k_c)^2}{4\delta(1 + k_b - k_c)} \right) + (1 - w) \left(\frac{(v - k_c)^2}{4(1 + k_b - k_c)} \right) - \beta w^2 \tag{xi}$$

From this the equilibrium $w^* = \frac{(1 - \delta)(v^2 - \delta k_c^2)}{8\delta\beta(1 + k_b - k_c)}$. When $\delta(2 + 2k_b - k_c) < v < 2(1 + k_b) - k_c$ the objective function for the innovator is:

$$\pi_i = w(v - \delta(1 + k_b)) + (1 - w) \left(\frac{(v - k_c)^2}{4(1 + k_b - k_c)} \right) - \beta w^2 \tag{xii}$$

which leads to $w^* = \frac{(v + k_c)^2 + 4(1 + k_b)(v + \delta(1 + k_b - k_c))}{8\beta(1 + k_b - k_c)}$.

When $k_c < v < \delta(2 + 2k_b - k_c)$, $\frac{\partial w^*}{\partial k_b} = \left(-\frac{1}{8\beta\delta(1 + k_b - k_c)^2} \right)(v^2 - \delta k_c^2)(1 - \delta) < 0$. Also $\frac{\partial w^*}{\partial k_c} = -\frac{(v^2 - 2\delta k_b k_c - 2\delta k_c + \delta k_c^2)(\delta - 1)}{8(1 + k_b - k_c)^2 \beta\delta}$ which is negative when $v < \sqrt{\delta k_c(2 + 2k_b - k_c)}$ and positive otherwise. Further, $\sqrt{\delta k_c(2 + 2k_b - k_c)} < \delta(2 + 2k_b - k_c)$ which establishes part 1 of the Proposition. When $\delta(2 + 2k_b - k_c) < v < 2(1 + k_b) - k_c$, $\frac{\partial w^*}{\partial k_c} = \frac{(v - 2k_b + k_c - 2)(v - k_c)}{8(1 + k_b - k_c)^2 \beta} > 0$ always. Further, $\frac{\partial w^*}{\partial k_b} = \frac{8\delta k_c - 2v k_c - 8\delta k_b - 4\delta + 8\delta k_b k_c + v^2 + k_c^2 - 4\delta k_b^2 - 4\delta k_c^2}{8(1 + k_b - k_c)^2 \beta}$. The numerator is negative when $v < k_c + 2\sqrt{\delta}(1 + k_b - k_c)$ and positive otherwise. Combining all this we have the comparative statics in part 2 and 3 of the Proposition. $\square$

Proof of Lemma 2

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 $\hat{t}_1 = \frac{p_s - k_c(1 - \delta)}{(1 - \delta)(1 + k_b - k_c)}$ and $\hat{t}_2 = \frac{(v - \delta k_c - p_s)}{\delta(1 + k_b - k_c)}$. The equilibrium price can be calculated to be $p_s^* = \frac{1 - \delta}{2} v$. Thus the equilibrium marginal consumers are $t_1^* = \frac{v - 2k_c}{2 + 2k_b - 2k_c}$ and $t_2^* = \frac{v + \delta(v - 2k_c)}{\delta(2 + 2k_b - 2k_c)}$.

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 $v > \frac{2(k_b+1)\delta}{1+\delta}$, all consumers in the market buy. Accordingly, when $2k_c < v < \frac{2(k_b+1)\delta}{1+\delta}$, profits for the monopoly innovator are $\pi_s = \frac{v^2(1-\delta)}{4\delta(1+k_b-k_c)}$. When $\frac{2(k_b+1)\delta}{1+\delta} < v < 1+k_b$, 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 $p_s^* = \frac{(1-\delta)(1+k_b)}{2}$. The profit then obtains by substituting the equilibrium price. $\square$

Proof of Proposition 2

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 π_s we obtain that when $2k_c < v < \frac{2(k_b+1)\delta}{1+\delta}$, $w^* = \frac{(1-\delta)v^2}{8\delta\beta(1+k_b-k_c)}$ and when $\frac{2(k_b+1)\delta}{1+\delta} < v < 1+k_b$, $w^* = \frac{(1-\delta)(1+k_b)^2}{8\beta(1+k_b-k_c)}$. When $2k_c < v < \frac{2(k_b+1)\delta}{1+\delta}$, $w_{cf}^* = \frac{(1-\delta)v^2}{8\delta\beta(1+k_b-k_c)}$ and $w_m^* = \frac{(1-\delta)\left(v^2-\delta k_c^2\right)}{8\delta\beta(1+k_b-k_c)}$, denote respectively the innovation investments under the competitive fringe and the pure monopoly. Therefore, $w_{cf}^* - w_m^* = \left(\frac{1}{8(1+k_b-k_c)\beta}\right)(1-\delta)k_c^2 > 0$. When $\frac{2(k_b+1)\delta}{1+\delta} < v < 1+k_b$, the monopolist facing a competitive fringe is in a situation of full market coverage which implies that $w_{cf}^* = \frac{(1-\delta)(1+k_b)^2}{8\beta(1+k_b-k_c)}$. When $v > \delta(2+2k_b-k_c)$, the pure monopoly innovator is also in a situation of full market coverage. Note that $\delta(2+2k_b-k_c) > \frac{2(k_b+1)\delta}{1+\delta}$ unless $\delta < \frac{k_c}{2+2k_b-k_c}$. Assume that the situation is one of full coverage independent of whether the monopolist faces a competitive fringe or not. Then $w_m^* = \frac{(v+k_c)^2+4(1+k_b)(v+\delta(1+k_b-k_c))}{8\beta(1+k_b-k_c)}$ and $w_{cf}^* - w_m^* = \frac{3\delta-4v+2k_b-4vk_b+2vk_c+6\delta k_b-4\delta k_c-4\delta k_b k_c+v^2+k_b^2+k_c^2+3\delta k_b^2+1}{8(1+k_b-k_c)\beta}$. 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 the Proposition. $\square$

Proof of Proposition 3

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

When $\frac{\delta((4-\delta)(1+k_b)-(1-\delta)k_c)}{2+\delta} < v < (1+k_b)$, the objective functions of the firm with the inno-

vation and the basic product will be $\pi_s = p_s(1 - \hat{t}_1)$ and $\pi_u = p_u \hat{t}_1$.[11] The equilibrium prices are $p_s^* = \frac{(1-\delta)(2+2k_b-k_c)}{3}$ and $p_u^* = \frac{(1-\delta)(1+k_b-2k_c)}{3}$. The profits can be derived to be $\pi_s^* = \frac{(1-\delta)(2+2k_b-k_c)^2}{9(1+k_b-k_c)}$ and $\pi_u^* = \frac{(1-\delta)(1+k_b-2k_c)^2}{9(1+k_b-k_c)}$. The comparative statics reported in part 2 of the Proposition follow. $\square$

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 $w^* = w_1^* = w_2^* = \frac{\pi_s^*}{\pi_s^* + \pi_u^* + 2\beta}$. We can calculate the relevant equilibrium w^* for partial and full coverage cases by substituting the relevant profits from Proposition 3.

Proof of Proposition 4

1. When $2k_c < v < \frac{\delta((4-\delta)(1+k_b)-(1-\delta)k_c)}{2+\delta}$, we can calculate $\frac{\partial w^*}{\partial k_c}$ and show that its sign is determined by the sign of the expression $v(1-\delta)(v-2k_c) + \beta(4-\delta)(2v-2\delta-2\delta k_b + \delta k_c)$. When $v > \frac{\delta(2+2k_b-k_c)}{2}$, then $\frac{\partial w^*}{\partial k_c} > 0$ because both terms are positive. When $v < \frac{\delta(2+2k_b-k_c)}{2}$ then $\frac{\partial w^*}{\partial k_c} < 0$ if $\beta > \frac{v(1-\delta)(v-2k_c)}{(4-\delta)(\delta(2+2k_b-k_c)-2v)}$. This proves part 1 of the proposition.

2. When $\frac{\delta((4-\delta)(1+k_b)-(1-\delta)k_c)}{2+\delta} < v < 1 + k_b$,
$\frac{\partial w^*}{\partial k_c} = \frac{6(2+2k_b-k_c)(1-\delta)\left(2k_b-\delta-2k_c+3\beta k_c-2\delta k_b+2\delta k_c-2k_b k_c+2\delta k_b k_c+k_b^2-\delta k_b^2+1\right)}{\left(18\beta-5\delta+10k_b-8k_c+18\beta k_b-18\beta k_c-10\delta k_b+8\delta k_c-8k_b k_c+8\delta k_b k_c+5k_b^2+5k_c^2-5\delta k_b^2-5\delta k_c^2+5\right)^2}$. The sign of $\frac{\partial w^*}{\partial k_c}$ is determined by $X_1 = 2k_b-\delta-k_c+9\beta k_c-2\delta k_b+\delta k_c-k_b k_c+\delta k_b k_c+k_b^2-\delta k_b^2+1$ because $\frac{6(2+2k_b-k_c)(1-\delta)}{\left(18\beta-5\delta+10k_b-8k_c+18\beta k_b-18\beta k_c-10\delta k_b+8\delta k_c-8k_b k_c+8\delta k_b k_c+5k_b^2+5k_c^2-5\delta k_b^2-5\delta k_c^2+5\right)^2} > 0$. Rewrite X_1 as $9\beta k_c + (1-\delta)(k_b+1)(1+k_b-k_c) \Rightarrow X_1 > 0 \Rightarrow \frac{\partial w^*}{\partial k_c} > 0$.

   Therefore, we have that when $\frac{\delta(1+k_b)-k_c}{2} < v < 1 + k_b$, then $\frac{\partial w^*}{\partial k_c} > 0$, which proves part 2 of the proposition. $\square$

Proof of Proposition 5

1. When $2k_c < v < \frac{(4k_b-\delta-k_c-\delta k_b+\delta k_c+4)\delta}{(\delta+2)}$, we can calculate $\frac{\partial w^*}{\partial k_b}$ and show that its is negative which proves part 1.

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

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