# Strategic Product Design

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**Abstract**

Product design changes targeting specific consumer groups are modeled as strategic responses of firms to different expectations about the market structure. Design competition followed by price competition leads to more specific products relative to the status quo and the social optimum. Anticipating price collusion or merger drastically reverses the incentive to produce more specific products. As the expectation of the probability of cartel formation (or merger) increases, the equilibrium product designs become less specific relative to the status quo. The paper establishes a ranking of these cases in terms of product specificity and the strength of ex post competition.

# 1 Introduction

Prior to the deregulation of the airline industry in 1978, airlines had little economic incentive to promote customer loyalty, and customers typically chose the most convenient flights. With the deregulation of pricing, passengers began choosing the least expensive flights, setting off fierce price competition among the airlines. Robert Crandell and American Airlines developed a clever means of softening price competition: the Frequent Flyer Program (FFP), introduced in 1981. Other airlines quickly copied the program. The program allowed the passengers to build up credits for each mile flown with the airline. These credits were redeemed for free flights. The FFPs make the flights via different airlines less substitutable by rewarding the customers to collect their flights under one roof (see Klemperer, 1992). Introducing the FFP reduces, for example, United's incentive to attempt to attract American's customers via price discounts, because a given price discount now attracts less customers due to less substitutability. Thus the FFPs soften price competition and help firms to attain higher levels of profits by locking-in customers.

In this paper, I show that when firms expect price competition, they invest in design changes that increase the value (or quality) of their products while making their products less substitutable in equilibrium, similar to introducing the FFPs.[1] Then I show that if firms form a research joint venture, i.e., collude in the product design stage, then the incentive to make the products more specific intensifies,

[1]Frequent Flyer Programs have a history dependence in the form of repeat purchases, but in this paper I consider their reduced form effects to product design. For more on Frequent Flyer Programs see Brandenburger and Nalebuff (1996).

but this time the product value (or quality) may not necessarily increase for all the firms.

Design changes that aim to lock-in consumers by making the products less substitutable are not unique to the travel industry. During the late 1990s in the multimedia market, Video CD player (VCD), a precursor to DVD player that is still widely used in Asia, faced competition from a forthcoming technologically superior, yet incompatible product, the DVD player. Around the time of introduction of the DVD player the number of VCD users were booming with a high adoption rate in East Asia. The estimated number of VCD users in China, for example, were around 20 million in 1997. Therefore, the prevailing success of VCD technology represented a great opportunity for a VCD-compatible product with superior technology to sidestep the DVD technology. Moreover, the Chinese government was concerned with the imposition of high royalty fees on the domestic electronic industry by the DVD consortium, tightly controlled by foreign firms. With the support of Chinese government, a group of manufacturers, later including Sony and Phillips, introduced another improved product called Super VCD (SVCD) in 1998. SVCD was particularly appealing to existing users of VCD because of compatibility. It would readily serve an established market of VCDs in especially East Asia, but it would not become much of a threat to consumers who prefer to buy a DVD, especially in the rest of the world where VCD is not commonly used. Thus SVCD was a design change targeting to lock-in the existing users of VCD players.[2]

[2]Details on how SVCD was developed are provided at

http://www.iki.fi/znark/video/svcd/overview.

The SVCD is a product design change that brings superior utility to all the consumers since it provides a superior technology relative to the existing product. However, it is also true that, the closer a consumer's initial taste is to the VCD, the more he benefits from SVCD. In this sense the development of SVCD can be modeled by a product design change in which value of the product increases (e.g. via a quality improvement) with the specificity of the product. Developing a more valuable and a more specific product simultaneously such as the SVCD fits into the equilibrium behavior predicted by the present model under duopoly expectation, similar to the FFPs.

The FFP and SVCD examples are intriguing because these design changes target the existing customers in contrast to the design changes in many other industries where firms offer price discounts to customers of the other firms or customers that are entirely new to the industry.

As suggested by the various examples above some product design changes provide relatively higher rewards to the existing customers, possibly in the form of loyalty rewards. Which strategy makes more sense given the future expectations about the market structure? This question is of central importance to this paper.

In this paper, I show that when firms expect to compete in prices they invest in design changes that target the existing customer base as in the FFPs or the SVCD examples. If the firms can collude at the product design stage prior to the pricing, that is, form a research joint venture, this incentive is reinforced: the equilibrium product designs are in general more specific relative to the case of price competition.

Cnet.com and zdnet.com, henceforth CNET and ZDNet[3], respectively, are two recently merged firms, previous leaders in the industry of providing technology related information. As stated in an article in BusinessWeek by David Shook[4] (ZDNet and CNET: Nearly Tied at the Top of the Tech Heap) published on June 3, 2000, a few months before the merger was announced, CNET and ZDNet were in head-to-head competition providing similar services for computer users, and using similar methods to survive the competition:

> "CNET and ZDNet offer a case study in head-to-head competition on the Web. Both review software and compare hardware performance. Both offer free downloads of games and provide computing tips. Both also publish news and analysis across the tech spectrum – from the Microsoft antitrust trial to the latest computer viruses. Without dispute, they're top destinations for information technology (IT) pros and buyers of computer and Web technology. And they're signing cross-marketing deals with other Web sites almost every month, seeking to attract more visitors and, ultimately, greater ad revenues."

A few months later, in October of 2000, CNET acquired ZDNet for $1.6 billion. Instead of focusing on a certain consumer group, CNET and ZDNet were making their services as substitutable as possible mainly targeting each

[3]The mixture of upper and lower case letters is the company usage.

[4]The article can be found at

http://www.businessweek.com/bwdaily/dnflash/june2000/nf00613g.htm?scriptFramed other's consumer base before the merger.[5]

The design changes performed by CNET and ZDNet that make the products less specific are different from the first two examples presented in this paper. However, when a merger is anticipated, the design changes of CNET and ZDNet also conform to the predictions of the model to be presented.

I analyze the incentives when firms are anticipating two forms of price collusion. The first model of price collusion coincides with a model of a merger where the future monopoly profits are shared via a bargaining process. The second possibility is collusion at the monopoly prices, where the profits are equally shared. In the unique SPNE of each case, the incentives related to product specificity are opposite of those found in the previous section: firms produce less specific products as the expectation of the probability of the success of a merger (or cartel formation) increases. In the final section of this paper, design changes in the previous sections are compared with the socially optimum ones. The paper concludes by providing a ranking of all the cases considered.

In the examples above, firms change product designs to treat consumers according to their initial preferences. In the standard application of spatial models

[5] Two other companies, hotjobs.com and monster.com attempted to merge in the Summer of 2001, following a similar product design pattern in the previous year. The merger failed because Yahoo! stepped in with a counter offer, and bought out hotjobs.com. More information can be found in the following links:

http://www.hotjobs.ca/htdocs/about/news-news/heck-of-a-job.html.

There was word of merger in the "on-line jobs" industry in 2000, evidence on possible merger anticipation in this industry can be found at

http://www.thestreet.com/tech/georgemannes/1479859.html.

to questions related to product differentiation, firms are generally allowed to choose a location in the product space, and $t$ is taken as an exogenous parameter. When a firm changes its location to become closer to a certain group of consumers, this move brings an equal utility increase for all the consumers that are closer now, but at the expense of an equal utility decrease for those consumers who are now further away (ignoring the consumers that are between the old and new positions). Such a repositioning of the firm is a poor model to represent loyalty rewards, or design changes targeting competitor's loyal customers, because of the equal effects on consumers. The examples from various industries above indicate that the firm can change the disutility of consumers in unequal magnitudes depending on their "distance" to the firm's product.[6]

In spatial models, the disutility of a consumer increases with the distance between his location (that represents the consumer's ideal product) and the firm's location (that represents the firm's product). The rate of change in the disutility of consumers as they are located further away from a firm's product is determined by a parameter $t$, traditionally called the transportation cost parameter. Making $t$ a choice variable for the firm, that is, endogenizing $t$, enables to model changes in a consumer's utility as a function of his location, which is a part of the modeling strategy that I employ. Von Ungern-Sternberg (1988) and Hendel and de Figueiredo (1997), use a similar modeling approach by endogenizing $t$, and compare the private and socially optimal product design incentives.

[6] Shaffer and Zhang (2000) tackle with preference-based price discrimination in markets with switching costs. They show that when demand is asymmetric it is possible that a firm charges a lower price to its own customers, whereas when the demand is symmetric a firm always charges a lower price to its rival's customers.

Von Ungern-Sternberg's (1988) static model implies less specific product designs in equilibrium relative to the social optimum, but the model does not consider strategic usage of product design in price competition. Hendel and de Figueiredo (1997) introduce a two-stage game, where the products are strategically designed in the first stage to affect the price competition in the second stage, and show that price competition may lead to more specific product designs to soften the price competition.

When the location of the firm is fixed a product with a lower $t$ brings a higher market share (other things being equal). In other words, a higher $t$ means a more specific product. For this reason I call $t$ the specificity factor throughout this paper. Changing the specificity factor $t$ alone does not account for some observed design changes where some customers benefit while others lose, since an increase (resp. decrease) in $t$ hurts (resp. benefits) every consumer. To account for a more general form of product design change I also allow the firms to make investments that change the valuation $v$ of the product (e.g. an increase in the quality of the product). For example, making the product both more valuable and more specific for all consumers may decrease final utilities of some consumers. In other words, the model allows for both vertical and horizontal differentiation simultaneously.[7,8]

[7]Barros and Martinez-Giralt (2002) consider quality competition of health insurance firms prior to price competition by endogenizing the valuation $v$ of the product. See also Schargrodsky and Sturzenegger (2000) who use a similar approach by allowing $v$ and $t$ to be a function of the same parameter. This latter method is not as general as the present approach, because it is impossible to make changes in, one of the parameters, say, $t$, without making a change in the other parameter $v$, a valid strategy under the present model, which proves useful in modeling research joint ventures.

[8]Weitzman (1994) shows that when $t$ is endogenous and location is also a choice variable, the Hotelling (1929) and Dixit-Stiglitz (1977) formulations of monopolistic competition models are isomorphic.

This paper goes beyond finding the equilibrium product diversity as an outcome of oligopolistic competition. The duopoly case that yields more specific designs than the status quo is initially established in Section 2 as a benchmark, but using a more general model of product design than the existing literature. In Section 3Research Joint Ventures are investigated. Sections 4 and 5 analayze merger and price collusion, respectively. Section 6 compares the previous results with the socially optimal product design changes. Section 7 concludes.

# 2 Duopoly

In the version of Hotelling's (1929) linear city model that I employ there is a continuum of (heterogeneous) consumers characterized by their location $z$ in the unit interval (see also Tirole (1988) and Mas-Collel, Whinston and Greene (1995)). The total measure of consumers is $M > 0$, but henceforth $M$ is normalized to 1. There are two firms whose locations are fixed at each end of the unit interval $[0, 1]$. Firms produce a homogeneous product with a constant unit production cost $c$, and the common valuation of each consumer for this product is $v$, where $v > c > 0$. The total utility of buying from firm $i$ for a consumer located at a distance $d \in [0, 1]$ from firm $i$ is $v - p_i - td$, where $p_i$ is the price of firm $i$'s product, and $t > 0$. The parameter $t > 0$ is traditionally interpreted as the transportation cost parameter, representing the rate of increase in the disutility of the consumer as his distance from the firm's product increases in the product space. The parameter $t$ also represents the specificity level of the product, since the lower $t$ is, the less specific a product becomes. (Recall that $t$ is called the specificity factor in this paper). Each consumer can buy at most one product. A consumer buys from firm $i$ if he derives non-negative utility from buying it and higher utility than buying from firm $j$.

In this section the two firms play a two-stage game. In the first stage each firm $i$ can invest in changing the valuation $v$ by $x_i$ and changing the specificity factor $t$ by $y_i$ incurring (fixed) costs represented by $f(x_i)$ and $g(y_i)$, respectively.[9] The resulting valuation and specificity factor of the product are respectively denoted with $v + x_i$ and $t - y_i$. Both the $x_i$'s and the $y_i$'s can have positive and negative signs. This stage constitutes the design competition stage of the game. The cost functions are differentiable as necessary, strictly convex and even. The "status quo", that is, the product design prior to the design changes represented by $(v, c, t)$, is defined as the minimum cost position, i.e., $f(0) = g(0) = 0$. Furthermore, I assume that $f'(0) = g'(0) = 0$, in order not to rule out a strategic design change because of its costliness. Note that both $f'(\cdot)$ and $g'(\cdot) = 0$ are odd and increasing functions, and both cost functions are common knowledge for the rest of the paper. In the second stage the firms determine the prices.

I proceed to find the pure strategy Subgame Perfect Nash Equilibrium (SPNE) of this game. In this paper equilibria in mixed strategies are not investigated, henceforth equilibrium refers to equilibrium in pure strategies. In the last stage,

[9] In general the cost functions need not be separable. A more general cost function $h(x, y)$, where $\frac{\partial^2 h(x,y)}{\partial x \partial y} \neq 0$ can be used to model some other cases. For example, for network goods a higher market share brings a higher valuation, and $\frac{\partial^2 h(x,y)}{\partial x \partial y} < 0$ may be appropriate for modeling these goods. Similarly, $\frac{\partial^2 h(x,y)}{\partial x \partial y} > 0$ may appropriately model a product such as a basketball shoe, whose value hardly increases when its specificity decreases for customers whose initial tastes are closer to the product. Furthermore, in a dynamic model the cost function can depend on the status quo, and can be written as $h(x, y; v, c, t)$.

the new valuation that the consumers have for the product of firm $i$ is $v + x_i$ and the new specificity factor with respect to firm $i$ is $t - y_i$ for each $i = 1, 2$. Cost-reducing R&D activities are not considered in this paper, thus the production cost $c$ does not change. The values, specificity levels and production costs of the products are exogenous in the second stage where firms decide on the prices only. The utility (in units of money) that a consumer derives from firm $i$ in this stage is

$$u_i(p_i; v, t, d, x_i, y_i) = v + x_i - p_i - (t - y_i)d.$$

Figure 1.1 illustrates the utilities of consumers in an asymmetric situation. In Figure 1.1, firm 1's product is more specific compared to firm 2's product, that is, $t - y_1 > t - y_2$. Also the prices ($p_i$'s) or the valuations ($v + x_i$'s) are not necessarily identical.

Depending on the prices of firms and the values of the other parameters the market may or may not be covered. The case where firms are local monopolies (leaving a part of the market uncovered), as called by Tirole (1988), is devoid of strategic interaction and is not my main focus. In this section, I concentrate on the case where market is covered with both firms having positive sales, which I call the "competitive case" following Salop (1979). I denote the demand in this case by $D_i$, where

$$D_i = \frac{(p_{-i} - x_{-i}) - (p_i - x_i) + t - y_{-i}}{2t - y_i - y_{-i}}.$$

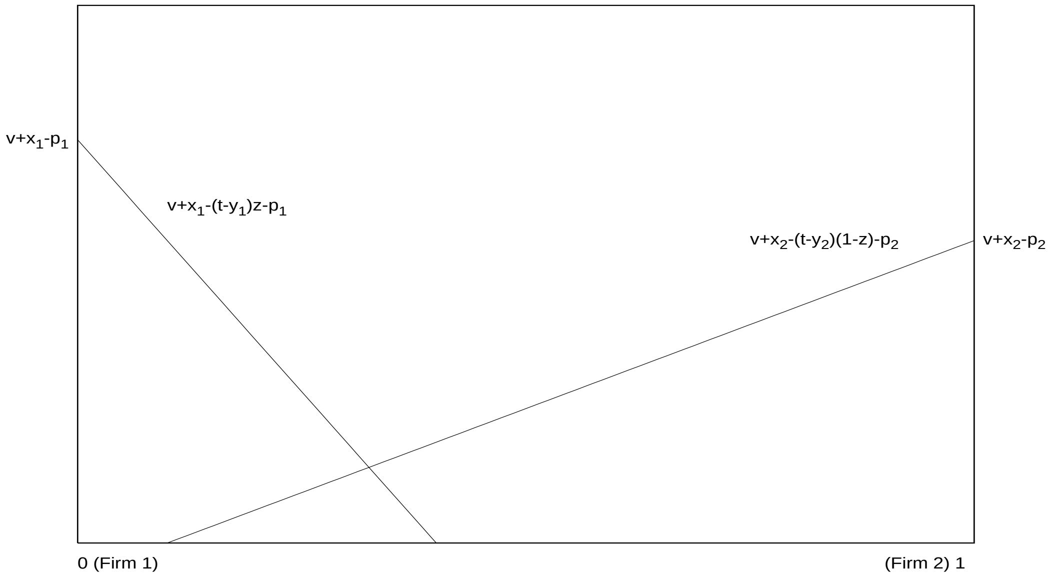


Figure 1: A possible representation of consumers' utility from each firm ($v, t$ $p_i's$, $x_i's$ and $y_i's$ are arbitrary). Firm 1 here has a higher specificity factor, that is, $t - y_1 > t - y_2$, hence its product is focused to the nearby consumers.

The competitive case requires $0 < D_i < 1$ for each $i = 1, 2$, which is the case when products are not too differentiated neither in vertical nor in horizontal dimensions. (The best response function corresponding to various cases of the overall demand function $D_i^O$ is available upon request). Firm $i$'s best response function in the second stage can be found by solving

$$max_{p_i}(p_i - c)D_i$$

I concentrate on the interior solution where markets strictly overlap, that is, $D_i \in (0, 1)$ and $\sum D_i = 1$.[10] The profit maximizing price for firm $i$ in the

[10]In the corner solution of this problem the firms want to make their markets independent, but this case is ruled out, thus the market ends up being barely covered, in the sense that the consumer who is indifferent to purchasing (with zero utility net of prices) is also indifferent to both firms. The Appendix lays out the assumptions for the corner solution, which is similar to "kinked equilibrium" in Salop (1979).

competitive case where markets overlap is

$$p_i^{br} = \frac{p_{-i} + x_i - x_{-i} + t - y_{-i} + c}{2}$$

From $p_i^{br}$ one can see that the prices are strategic complements, that is, $\frac{dp_i^{br}}{dp_{-i}} > 0$. The existence and uniqueness of a (pure strategy) Nash equilibrium in the first stage is guaranteed by assuming that $x_i - x_{-i} + t - y_{-i} + c > 0$ for each $i = 1, 2$. The $x_i$'s and $y_i$'s can be written in terms of cost functions evaluated in the equilibrium value of interest. This assumption provides a positive intercept to each $p_i^{br}$, and by restricting the difference between the final valuations, it guarantees positive profits for each firm. In the case of symmetry is imposed this assumption boils down to $c + t - y > 0$, and in what follows I show that the symmetric equilibrium price equals $c + t - y$.

The corresponding Nash Equilibrium (NE) price of firm $i$ in the last stage is:

$$p_i^{NE} = c + t + \frac{x_i - x_{-i}}{3} - \frac{y_i + 2y_{-i}}{3}.$$

Note that, the symmetric equilibrium price in the status quo (without the design competition at the first stage) is given by $p = c + t$ for each firm $i$ (see Mas-Collel, Whinston, and Greene, 1995). The Nash Equilibrium price $p_i^{NE}$ illustrates that any absolute increase $x_i$ in the quality of the product translates into a price increase for the firm $i$ in equilibrium only if the firm provides a higher valuation relative to firm $-i$, that is, only if there is an increase in $x_i - x_{-i}$. In the symmetric case the effect of quality improvement $x_i$ on the price is undone by the move of the competitor. An increase in $y_i$ or $y_{-i}$ makes products closer substitutes, and such an increase intensifies the price competition between the products as reflected in $p_i^{NE}$. But a decrease in $y_{-i}$, not only decreases the substitutability between the products, but also causes firm $i$ to lose some market share in the first place. For these reasons, the negative effect of an increase in $y_{-i}$ on $p_i$ is two times that of the same increase in $y_i$.

The resulting demand and profits in the first stage for firm $i$ are

$$D_i^{NE} = \frac{(t + \frac{x_i - x_{-i}}{3} - \frac{y_i + 2y_{-i}}{3})}{2t - y_i - y_{-i}},$$

$$\Pi_i^{NE} = (2t - y_i - y_{-i})(D_i^{NE})^2.$$

In the first stage of the game firm $i$ decides on how much to change the valuation of the product and the specificity factor maximizing $\Pi_i$ with respect to $x_i$ and $y_i$. The first order conditions of firm $i$'s problem is:

$$f'(x_i) = \frac{2}{3} D_i, \tag{1}$$

$$g'(y_i) = D_i^2 - \frac{2}{3} D_i. \tag{2}$$

I assume that the design changes are costly enough so that a firm can not foreclose the market to its competitor, and the firms remain in the competitive duopoly case. This assumption requires such cost functions that in equilibrium $x_i - x_{-i}$ is relatively small in absolute value compared to $t - y_i > 0$ for each

i. If $f(\cdot)$ and $g(\cdot)$ is sufficiently convex, then there exists a unique maximizer for firm $i$ rendering the unique symmetric SPNE. The details are laid out in the Appendix. Proposition 1 summarizes the findings in symmetric equilibrium.

*Proposition 1:* In the symmetric equilibrium both firms provide design changes that target the existing consumer bases by simultaneously increasing both the valuation and the specificity of the product, that is, $\forall i \epsilon \{1,2\} \quad x_i^* = x^* > 0 > y_i^* = y^*$, where $^*$ denotes duopoly.

*Proof:* In a symmetric equilibrium the demand for both firms equals $\frac{1}{2}$. Both $f(\cdot)$ and $g(\cdot)$ are strictly convex, hence ${f'}^{-1}(\cdot)$ and ${g'}^{-1}(\cdot)$ are increasing functions. Recall that ${f'}^{-1}(0) = {g'}^{-1}(0) = 0$, hence it is easy to see that, $x^* = {f'}^{-1}(\frac{1}{3}) > 0 > y^* = {g'}^{-1}(-\frac{1}{12})$. Then $v + x^* > v$ and $t - y^* > t$. $\square$

According to Proposition 1, $t - y^* > t$, that is, in the symmetric equilibrium of the competitive duopoly case, both firms perform design changes that result in more specific products compared to the status quo. More specific products hamper the competitor's gains in market share via price discounts. Furthermore $v + x^* > v$, thus the equilibrium design changes yield relatively more utility to the existing consumer base, similar to the introduction of the Frequent Flyer Programs or the SVCD player.

The design changes bring an opportunity to charge a higher price $p^*$ in the symmetric equilibrium compared to the status quo price $p$, i.e.,:

$$p^* = c + t - y^* > c + t = p$$

The optimal profits with the design changes are greater than the optimal profits without the design changes if and only if $-\frac{y^*}{2} - f(x^*) - g(y^*) > 0$, for example when $f(u) = g(u) = u^a$, $a \geq 2$.

The equilibrium horizontal differentiation to relax price competition is in the same spirit with d'Aspremont, Gabsewicz and Thisse (1979), but the modeling strategy here is more similar to Hendel and de Figueiredo (1997). Along the same lines, but in a model of vertical differentiation, Shaked and Sutton (1982) show that firms differentiate to relax price competition.[11] Irmen and Thisse (1998) show that when there are more than one horizontal characteristics, the principal of maximum differentiation applies only in one dimension, whereas the principal of minimal differentiation applies in all the others. My result is reminiscent of Irmen and Thisse (1998) since there is no differentiation in quality dimension, whereas firms differentiate in the specificity dimension.

A useful aspect of the proposed general form of product design changes that I use is that it enables to model an increase in the utility of consumers (net of prices) in equilibrium, even though the prices and specificity levels of the products increase in equilibrium. If firms are unable to increase the valuations, all consumers lose in the symmetric equilibrium with higher specificity levels due to higher equilibrium prices relative to the status quo. Since the market is always covered, increases in the profits do not surpass the absolute value of the decrease in consumer surpluses due to the higher product specificities. Differentiating, and consequent price increases unambiguously reduce the social welfare. But in the general form of product design changes I introduce, depending on the cost

[11] Bergemann and Välimäki (1997) analyze the diffusion of a newly designed product of uncertain value in a dynamic duopoly context. Both firms benefit from sales of the new design introduced by one of the firms, a factor relaxing the price competition.

functions, a variety of changes in the utility of the consumers (net of prices) is possible. In Figure 1.2, these possibilities arising from the following conditions are shown, where (3), (4) and (5) are defined as follows:

$$x^* + \frac{3}{2}y^* > 0 \tag{3}$$

$$x^* + y^* > 0 > x^* + \frac{3}{2}y^* \tag{4}$$

$$x^* + y^* < 0 \tag{5}$$

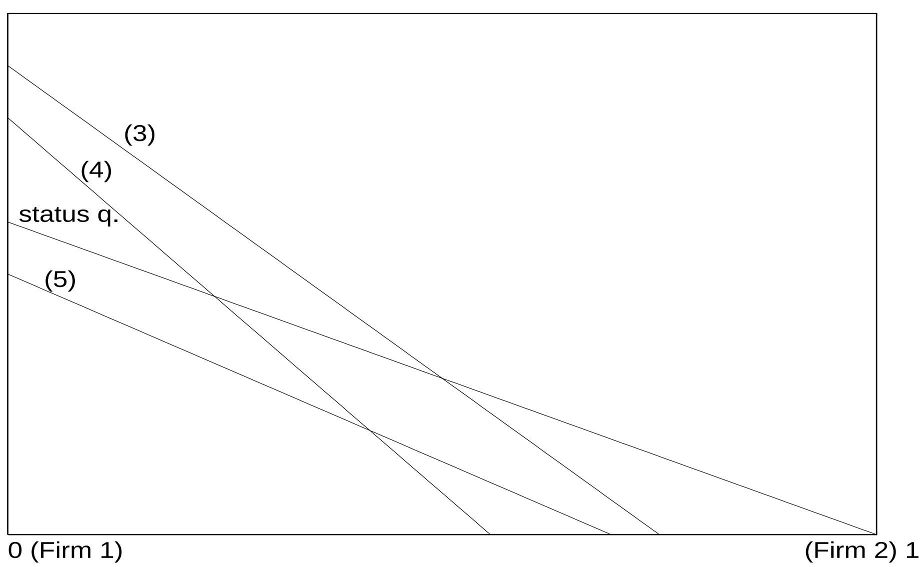


Figure 2: Possible changes in the utilities of consumers in the competitive duopoly equilibrium. Note that firm 1 covers more than half of the market, and the utilities of consumers from firm 2 are not displayed due to symmetry in equilibrium.

In any of these cases the consumers who are close to the firm are relatively better as a result of the design changes. If (3) (resp. (5)) holds, then all consumers of firm 1 strictly benefit (resp. lose) from the design changes in equilibrium, and if (4) holds only the consumers who are close to the firm strictly benefit from the design changes. For example, let $f(u) = g(u) = u^a$. Then (3) holds if $a = 2$, and (4) holds with $a = 4$. Figure 1.3 shows utilities from both firms when (4) holds.

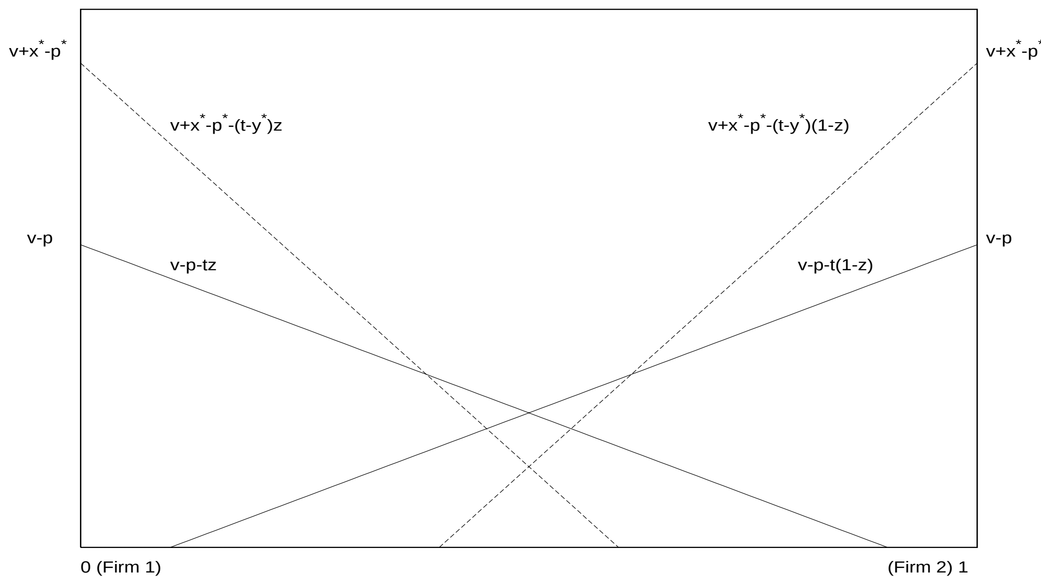


Figure 3: Firms' efforts to increase loyalty by changing the product design in duopoly at the symmetric equilibrium. (The superscript * indicates equilibrium values with design competition, whereas $p$ is the status quo equilibrium price.)

As a final remark I consider the static game, similar to that of Von Ungern-Sternberg (1988), where price and design competition takes place simultaneously, but using the more general form of product design changes in this paper. It can easily be checked that simultaneous design and price competition yields the following first order conditions for firm $i$:

$$f'(x_i) = \sqrt{g'(y_i)} = D_i.$$

The symmetric equilibrium yields (the superscript $^{sim}$ refers to the equilibrium values):

$$x^{sim} = f'^{-1}(\frac{1}{2}) \quad \text{and} \quad y^{sim} = g'^{-1}(\frac{1}{4}).$$

(The conditions for the existence and uniqueness of a symmetric equilibrium are similar to the previous case). The incentive to produce more specific products disappears here because of no strategic interaction between the designs and prices. The firms decrease the specificity of the products as long as the benefit to the marginal consumer from decreased specificity is more than the cost of decreasing specificity. Via decreasing specificity firms can increase the prices and profit from the design change without worrying about its effect on price competition. Similarly, firms only consider the marginal cost of $x_i$ and the marginal consumer's benefit from $x_i$ when deciding on the level of $x_i$.

This section constitutes the benchmark as the case where there is no design collusion. Now I introduce the case of duopoly with design collusion, i.e. the research joint venture.

# 3 Research joint venture

Firms' relationship might include various forms of cooperation, while competition in prices may simultaneously be taking place. Research Joint Ventures (RJVs), where competing firms cooperate in R&D prior to price competition activities constitute a prominent example to this situation as in d'Aspremont and Jacquemin (1988). In similar spirit, I assume that instead of engaging in design competition, firms collude in the design stage, acting as one decision-maker whose aim is to maximize the future industry profits. Hence the price competition stage remains the same as in the previous section. The industry profit is the summation of $\Pi_i^{NE}$ in the previous subsection, and firms jointly maximize the industry profit in the first stage. Hence, the problem of the firms in the first stage becomes

$$max_{x_1,x_2,y_1,y_2} \sum_{i=1}^{2} \Pi_i^{NE}$$

Utilizing the first order conditions, the unique SPNE design changes (denoted by the subscript $^{rjv}$) are given by $(i = 1, 2)$:

$$f'(x_i^{rjv}) = \frac{2}{3}(\Pi_i^{rjv} - \Pi_{-i}^{rjv}) = \frac{2}{3}(2t - y_i - y_{-i})(D_i^{rjv} - D_{-i}^{rjv}) \qquad (6)$$

$$g'(y_i^{rjv}) = 2(D_i^{rjv})^2 - \frac{4}{3}D_i^{rjv} - \frac{1}{3}, \qquad (7)$$

where the variables with the superscript $^{rjv}$ refer to the equilibrium values. It is straightforward to show that whenever it exists the equilibrium is always asymmetric.[12] (See the Appendix for details). From equation (1.6) it is clear that in equilibrium firms never simultaneously increase the values of their products as opposed to duopoly. Firms have the incentive to set asymmetric $x_i$'s that are equal in absolute value, since profits increase as one of the firms gains a higher

[12] A similar observation can be found in Salant and Shaffer (1999).

market share.[13] A comparison of equations (1.7) and (1.2) shows that in general the range of market shares that yield $y_i < 0$ in equilibrium in the case of RJV is a superset of that of duopoly. When the firms can collude on design changes, they design more specific products in order to be able to further soften the price competition, and to concentrate on their respective niches. When products are more specific, both firms can increase prices without triggering a harsh response from the competitor. As can be seen from the first order conditions, unless one of the firms have a very high market share (approximately at least .86), the equilibrium product designs are more specific relative to the status quo. Under the research joint venture, at least one firm provides more specific products than duopoly, but the welfare implications are ambiguous, since $x_i^{rjv} > 0 > x_{-i}^{rjv}$ for some $i$.

Significant deviations from the symmetric outcome may lead to lower profits for some firms as seen from equation (1.6), hence some firms may not participate in the RJV. Note that the symmetric equilibrium prices increase due to design collusion compared to the case without design collusion, that is, $p^{rjv} = c + t - g'^{-1}(-\frac{1}{2}) > p^* = c + t - g'^{-1}(-\frac{1}{12})$. In this case RJV still represents an improvement in industry profits relative to the competitive duopoly. Hence a participation constraint dictating the symmetric outcome is feasible. Proposition 2 presents the symmetric outcome dictated by a participation constraint.

*Proposition 2:* The symmetric equilibrium design changes render no change in the valuation $v$ of the product and a more specific product than the duopoly

[13] For another model where a firm can strategically decrease the valuation of its own product in equilibrium, see Davis, Murphy and Topel (2001).

case, that is, $x^* > x^{rjv} = 0$ and $y^* > y^{rjv} = {g'}^{-1}(-\frac{1}{2})$.

*Proof:* The symmetric solution renders equal profits, making $f'(x^{rjv}) = 0$, hence $x^{rjv} = 0$. Plugging in $\frac{1}{2}$ for $D_i^{rjv}$ for each $i$, $g'(y_i^{rjv}) = -\frac{1}{2}$, hence ${g'}^{-1}(-\frac{1}{2}) = y^{rjv}$.□

Now I proceed to the cases where I investigate the product design incentives of colluding firms.

# 4 Merger

In this section the two firms play a three stage game. The first stage is the same as the previous section: firms can invest in changing both the specificity factor $t$ by $y_i$ incurring the cost $g(y_i)$ and the valuation $v$ by $x_i$ incurring the cost $f(x_i)$. All assumptions in the previous section related to the cost functions are retained. In the second stage whether the merger is successful is revealed by nature. At this stage both firms expect to merge with an exogenous probability. This probability represents firms' perception of the exogeneous factors such as the antitrust policy, the possibility of another firm stepping in and making a counter offer, or the personalities of CEOs (see McAfee et al. (1993) for an example where personalities may matter).[14] In the last stage the two firms are centrally managed if the merger is successful. At this stage the central management decides how to price. If merger is not successful the firms play the competitive duopoly game, as in the previous section. I solve the game via backward induction. The following

[14]As a practical matter, decreasing specificity actual.ly increases the likelihood of a DOJ challenge but such an analysis would require the analysis in the present paper as a starting point.

proposition sheds light on the pricing behavior of the centrally managed firms in the final stage. (In the Appendix I show that shutting down one of the firms is never optimal for the central management).

*Proposition 3:* Assume that serving the whole market is profit maximizing for the central management in the second stage, i.e., $\sum \frac{v+x_i-c}{2(t-y_i)} \geq 1$. Then the consumer that is indifferent between the two products is also indifferent to purchasing. Any further price increase would lead some consumers unserved.

*Proof:* See the Appendix. □

The assumption in Proposition 3 is that the sum of the optimal market shares in the local monopolies case exceeds 1, which implies that it is not optimal to leave any portion of the market unserved. This assumption holds if the value $v$ of the product, net of the unit production cost $c$, is high relative to $t$. Under this assumption, by virtue of Proposition 3, the problem of the central management reduces to

$$max_{p_i,p_{-i}} \sum_{i=1}^{2}(p_i - c)\frac{v + x_i - p_i}{t - y_i} \quad \text{s.t.} \quad \sum_{i=1}^{2} \frac{v + x_i - p_i}{t - y_i} = 1$$

Maximizing the above profit function when the equality constraint is binding gives the optimal solution. Thus the optimal prices when merger takes place and the resulting demand are

$$p_i^m = (v + x_i) - ((t - y_{-i}) - \frac{x_{-i} - x_i}{2})\frac{t - y_i}{2t - y_i - y_{-i}},$$

$$D_i^m = \frac{x_i - x_{-i} + 2(t - y_{-i})}{2(2t - y_i - y_{-i})}.$$

The resulting profits are given by

$$\Pi^m = v - c + \frac{\frac{(x_1-x_2)^2}{4} + x_1(t-y_2) + x_2(t-y_1) - (t-y_1)(t-y_2)}{(2t-y_1-y_2)}.$$

I assume that the buyout price (or more precisely, the value of the merger to the firm) is determined as a result of bargaining. Using the Nash Bargaining solution, the buyout price for firm $i$ is found by dividing the surplus $\Pi^m - \Pi_i^{NE} - \Pi_{-i}^{NE}$ equally and adding this to the outside option of firm $i$.[15,16] The resulting buyout price is given by $\Pi_i^{NB}$ ($NB$ standing for Nash Bargaining):

$$\Pi_i^{NB} = \frac{1}{2}[\Pi^m + \Pi_i^{NE} - \Pi_{-i}^{NE}]$$

where, noting $D_i^{NE} + D_{-i}^{NE} = 1$, it can be shown that,

$$\Pi_i^{NE} - \Pi_{-i}^{NE} = \frac{1}{3}(2(x_i - x_{-i}) + (y_i - y_{-i})).$$

First, I restrict my attention to the case where merger is certainly going to take place if it is accepted by both firms and proceed to the final stage of the game. (The general case is analyzed in the next subsection). Thus, what reduces to the first stage is the merger price determined by Nash bargaining solution where duopoly profits are outside options. In the first stage of the game firms decide on how much to change the valuation of the product and the specificity

[15] The other case where firms' local monopoly profits are outside options yields qualitatively similar results.

[16] Note that using the term "outside option" instead of the term "threat point" is in compliance with Chiu (1998) since once a merger is rejected it is final.

factor. Firm $i$'s problem in the first stage can be stated as:

$$max_{x_i,y_i}\Pi_i^{NB} - f(x_i) - g(y_i)$$

The first order conditions for firm $i$ are:

$$f'(x_i) = \frac{1}{2}D_i^m + \frac{1}{3}, \tag{8}$$

$$g'(y_i) = \frac{1}{2}D_i^{m^2} + \frac{1}{6}. \tag{9}$$

The existence and uniqueness of a symmetric SPNE is achieved under conditions that are similar to the case of duopoly: the high costs of making too drastic design changes should force firms choose their product design changes so as to remain in the competitive duopoly case (see the Appendix). Proposition 4 presents the symmetric equilibrium:

*Proposition 4:* When firms are anticipating a merger with certainty, the symmetric equilibrium yields less specific products compared to the case of duopoly. The valuation of the products with merger anticipation is greater than the valuation in the case of duopoly. In summary, $x^m > x^* > x^{rjv} = 0$ and $y^m > 0 > y^* > y^{rjv}$.

*Proof:* Note that the optimal market size $D_i^m$ equals $\frac{1}{2}$ in the symmetric equilibrium. Hence equilibrium designs are given by $x^m = f'^{-1}(\frac{7}{12}) > 0$ and $y^m = g'^{-1}(\frac{7}{24}) > 0$, leading to a more valuable and less specific product since $v + x^m > v$ and $t - y^m < t$. $\square$

The design incentives drastically change in the case of merger relative to duopoly. In other words, anticipating a merger mitigates product differentiation as opposed to anticipating price competition.[17] Each firm invests in design changes targeting customers of the competitor as in the case of CNET and ZDNet prior to their merger. Firms make their products less specific for two reasons. First the relative bargaining power of firm $i$ $(\Pi_i^{NE} - \Pi_{-i}^{NE})$ increases with more valuable and less specific products. Even though the firm itself is hurt by a less specific product the competitor is hurt more. Second, as long as the cost of producing more valuable and less specific products is less than the benefit to the marginal consumer, firms can increase the prices by corresponding amounts, increasing the profits for each firm, thus the centralized firm's overall profits.

In Figure 1.4, the symmetric equilibria in the competitive case and the merger anticipation are compared.

Note that $p^m = v - \frac{t}{2} + x^m + \frac{y^m}{2}$. The design changes bring an opportunity to charge a higher price in the symmetric equilibrium compared to the symmetric equilibrium price without the design changes, given by $v - \frac{t}{2}$, since $x^m, y^m > 0$. Comparing the post-merger price $p^m$ with $p^{rjv}$ yields $p^m > p^{rjv}$ if

$$v - \frac{3t}{2} - c + {f'}^{-1}(\frac{7}{12}) + \frac{1}{2}{g'}^{-1}(\frac{7}{24}) + {g'}^{-1}(-\frac{1}{2}) > 0. \tag{10}$$

Note that $v - \frac{3t}{2} - c = v - \frac{t}{2} - (c + t)$, that is, the difference between the prices in the cases of merger anticipation and duopoly in the absence of design

[17]Bester (1998) points out that another factor that mitigates product differentiation is quality uncertainty.

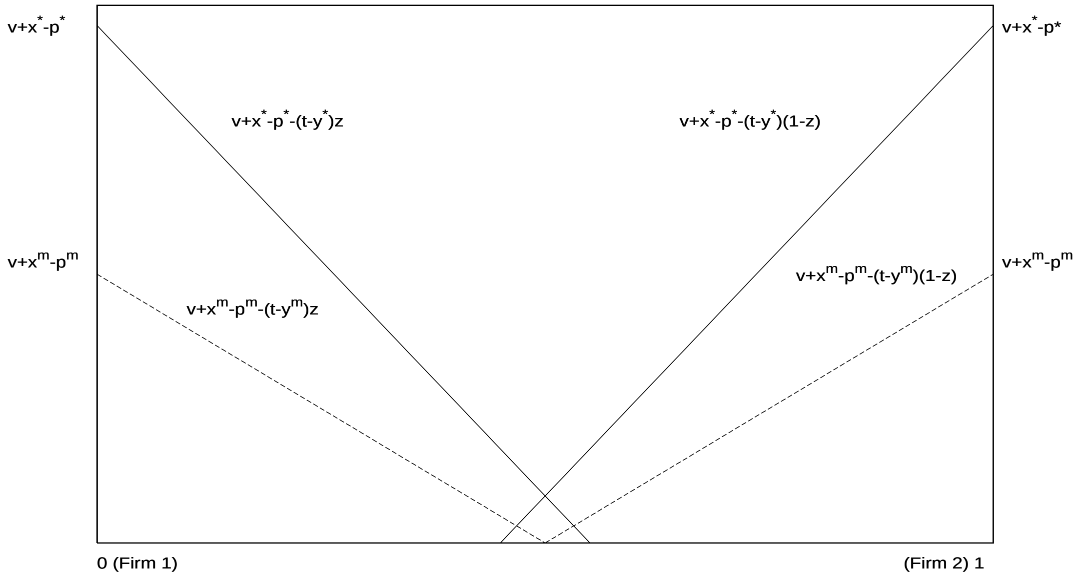


Figure 4: The equilibrium prices in the case of merger anticipation are higher than the equilibrium prices in the case of duopoly, causing social welfare to decrease. (The superscripts $^m$ and $^*$ denote the cases of merger anticipation and duopoly, respectively).

competition. As mentioned in Mas-Collel, Whinston and Green (1995), $v - \frac{3t}{2} - c \geq 0$ is the necessary condition for the existence of equilibrium in the pricing game. As $g'$ becomes more convex, $g'^{-1}$ becomes more concave, and $\frac{1}{2}g'^{-1}(\frac{7}{24})+g'^{-1}(-\frac{1}{2})$ goes to zero. Then it suffices for $p^m > p^{rjv}$ that $v-\frac{3t}{2}-c > 0$, since $f'^{-1}(\frac{7}{12}) > 0$.[18]

## 4.1 Uncertain merger

Firms anticipating a merger are aware of the DOJ policy with respect to mergers. DOJ determines whether to challenge a merger primarily depending on the prior

[18] Since in the competitive case the market is covered $v + x^* - p^* > v + x^m - p^m$ has to hold. This condition is similar to equation 2.3 and can be written as

$$v - \frac{3t}{2} - c + f'^{-1}(\frac{1}{3}) - f'^{-1}(\frac{7}{12}) + g'^{-1}(\frac{-1}{12}) + g'^{-1}(\frac{7}{24}) > 0,$$

which holds for example when $f(u) = g(u) = u^2$. If this condition does not hold, then local monopolies case prevails.

to and post merger Herfindhal-Hirschman Index (HHI)[19] There is uncertainty especially when the level and the change in the HHI is in the specified intervals that the DOJ does not necessarily let go or challenge the merger, but it investigates the case further. In compliance with the spirit of Lucas Critique (1979), I include the expectations of the firms about the government policies into their decision making process. A simple way to incorporate these expectations about the DOJ policy to the game is to introduce an exogenous probability of merger success $P^m$, commonly known by both firms. This probability may depend on product designs, but in this study I do not pursue that route.

*Proposition 5:* As $P^m$ increases the equilibrium value of $t - y_i$ decreases, that is, with a higher probability of merger, the less differentiated are the products.

*Proof:* The average of the first order conditions of the competitive duopoly and certain merger anticipation cases, weighted by the probability of success $P^m$, constitute the first order conditions of the present problem. As $P^m$ increases the first order conditions of the merger solution gain more weight, rendering the proposed equilibrium. □

One can find a cutoff probability where the incentive to increase the specificity of the product vanishes and develops in the opposite direction denoted by $P^{m,cut}$. For the symmetric case the value of $P^{m,cut}$ that renders no incentive to change the specificity factor $t$ can be found from

$$P^{m,cut} g'(\frac{-1}{12}) + (1 - P^{m,cut}) g'(\frac{7}{24}) = 0. \tag{11}$$

[19]This index equals the sum of squared market shares in percentages.

In the case where $f(u) = g(u) = u^2$, (5) renders $P^{m,cut} \cong \%78$. It is easy to see that this probability decreases with increasing convexity of cost functions. Hence, in the symmetric equilibrium, unless the firms think that $P^{m,cut}$ is sufficiently high they do not invest in producing less specific products than the status quo. The less the merger has a chance to be successful, the more the incentives to avoid cut throat competition become, and hence the design changes towards consumer loyalty become effective. The firms switch their design strategy from specific to general purpose products to the extent that they are sure of approval of the merger.

# 5 Price collusion

There is no consensus on the best price collusion model. For example, Cave and Salant (1995) use a voting model to analyze the choice of quotas by legal cartels. Also, the case of merger covered in Section 5 coincides with a model of price collusion where profits are shared via a bargaining process. In this section I analyze another price collusion model where monopoly profits are equally shared.[20]

As a benchmark for this section, consider the case of (static) monopoly, where the central management that operates the two firms determines the prices and product designs simultaneously. Retaining the assumption that serving the whole market is optimal, i.e., $\sum \frac{v+x_i-c}{2(t-y_i)} \geq 1$, the monopoly barely covers the market by virtue of Proposition 3 (as in the previous section). The monopoly profit

[20] Combined with the merger model in Section 5, the results in this section can also help to analyze the effects of outside options on product design in merger, but I do not pursue this route in this dissertation.

$\Pi^m$ is given in the previous section as a function of $x_i$'s and $y_i$'s. For ease of exposition, the monopoly can be thought of maximizing with respect to prices first, and with respect to the design changes in the following stages. Thus the monopoly problem can be solved by first maximizing $\Pi^m$ with respect to prices. Then, the product designs can be determined by solving

$$\max_{x_1,x_2,y_1,y_2} \sum \Pi^m - \sum (f(x_i) + g(y_i))$$

The FOCs are $(i = 1, 2)$

$$f'(x_i) = D_i^m,$$

$$g'(y_i^m) = D_i^{m^2}.$$

The profit maximizing design changes are not symmetric in the case of monopoly, similar to the RJV. But the product valuations increase and product specificities decrease for both firms. These design changes are socially beneficial other things being equal. It is noteworthy that the socially optimal design changes are very similar (see Section 7) to the case of monopoly. The ability of a multi-product monopoly to coordinate the pricing structure better leads to better design incentives relative to duopoly as pointed out by Davis, Murphy and Topel (2001).

Now, assume that the firms expect to collude in the second stage with certainty at monopoly prices given above, and they share the profits equally. Then the firm $i$'s problem in the first stage becomes,

$$max_{x_i,y_i}\frac{\Pi^m}{2} - f(x_i) - g(y_i).$$

The conditions for the existence and uniqueness of a symmetric SPNE are very similar to those in the case of merger in Section 5. Then the following proposition is easily achieved (the superscript $^{pc}$ denotes price collusion):

*Proposition 6:* In the symmetric equilibrium, collusion on the monopoly price with certainty renders less valuable and more specific products compared to the case of merger anticipation, but less valuable and less specific products compared to the case of duopoly. In summary, $x^m > x^* > x^{pc} > 0 = x^{rjv}$ and $y^m > y^{pc} > 0 > y^* > y^{rjv}$, where $(x^{rjv}, y^{rjv})$ are symmetric equilibrium design changes in the case of RJV arising from a participation constraint.

*Proof:* Symmetric equilibrium renders $f'(x_i^{pc}) = \frac{1}{4}$ and $g'(y_i^{pc}) = \frac{1}{8}$. $\square$

## 5.1 Uncertain price collusion

Let $P^{pc}$ represent the probability of successful collusion. Similar to the case of merger anticipation in Section 5, such an exogenous probability models, for example, the managers' personalities or their views on the likelihood of court challenges. Assume that if cartel fails to form, firms resort to the competitive duopoly. In this case all the range of designs between the equilibrium design in duopoly and price collusion can be achieved in equilibrium as a function of $P^{pc}$.

*Proposition 7:* In equilibrium firms would like to differentiate less, the higher the probability of cartel formation $P^{pc}$ is, that is, as $P^{pc}$ increases the equilibrium value of $t - y_i$ will decrease.

*Proof:* Similar to the proof of Proposition 6.□

The higher the likelihood of the price collusion, the lower the incentives to avoid cut throat competition, and hence design changes towards consumer loyalty are not effective. Instead, the firms switch their design strategy from specific to general purpose products. With the general purpose products they can expropriate the additional utilities provided, as long as the benefit to the marginal consumers net of design costs can be transferred to firms via price increases.

One can find a cutoff probability where the incentive to increase the specificity of the product vanishes and develops in the opposite direction. For the symmetric case the cutoff probability of success of merger (denoted by $P^{pc,cut}$) that renders no incentive to change the specificity factor $t$ can be found from

$$P^{pc,cut} g'(\frac{-1}{12}) + (1 - P^{pc,cut}) g'(\frac{1}{8}) = 0. \tag{12}$$

In the case where $f(u) = g(u) = u^2$, (14) renders a smaller probability compared to the similar cutoff probability in the case of merger, $P^{pc,cut} \cong \%60 < P^{m,cut}$. Hence, the bargaining power in sharing the division of the future pie also affects the equilibrium specificity levels of products. In the symmetric equilibrium, unless firms think that $P^{pc,cut}$ is sufficiently high they do not invest in producing less specific products. The less the cartel is likely to be formed, the more the incentives to avoid cut throat competition, and hence design changes towards consumer loyalty are effective. The firms switch their design strategy from specific to general purpose products to the extent that they are sure of formation of the cartel.

The next step is finding the socially optimum product design changes.

# 6 Social optimum

In this section I find the socially optimum solution when two firms cover the market to be consistent with previous sections.[21] The utility that a consumer derives from firm $i$ is the same as previous sections, except that there are no prices:

$$u_i(v, t, d, x_i, y_i) = v + x_i - (t - y_i)d.$$

The social welfare can be represented by subtracting the production cost of serving the whole market $c$ and the costs of design changes from the area under the curve $max\{u_i, u_{-i}\}$ that form two adjacent trapezoids. From Figure 1.5, one can see that this area consists of two parts: the rectangle $A$ under the dashed line and the sum of the two triangles above the dashed line and below the utility curves, $B$, where $B = B_1 + B_2$. Note that

$$A = v + x_i - (t - y_i)\bar{D}_i^s \quad \text{and} \quad B_i = \frac{t - y_i}{2}(\bar{D}_i^s)^2$$

where $\bar{D}_i^s = \frac{x_i - x_{-i} + t - y_{-i}}{2t - y_i - y_{-i}}$. The social planner maximizes social welfare (SW) given by

$$SW = v - c + \frac{x_1(t - y_2) + x_2(t - y_1) + \frac{(x_1 - x_2)^2 - (t - y_1)(t - y_2)}{2}}{2t - y_1 - y_2} - \sum_{i=1}^{2}(f(x_i) + g(y_i)).$$

[21]It is worth noting that the Ramsey solution would yield the same design changes with the social optimum in this section because I assume that the market demand is not downward sloping.

Note that the monopoly and the social planner problems are similar, and $SW > \Pi^m$ since:

$$SW = \Pi^m + \frac{(x_1 - x_2)^2 + 2(t - y_1)(t - y_2)}{4(2t - y_1 - y_2)}.$$

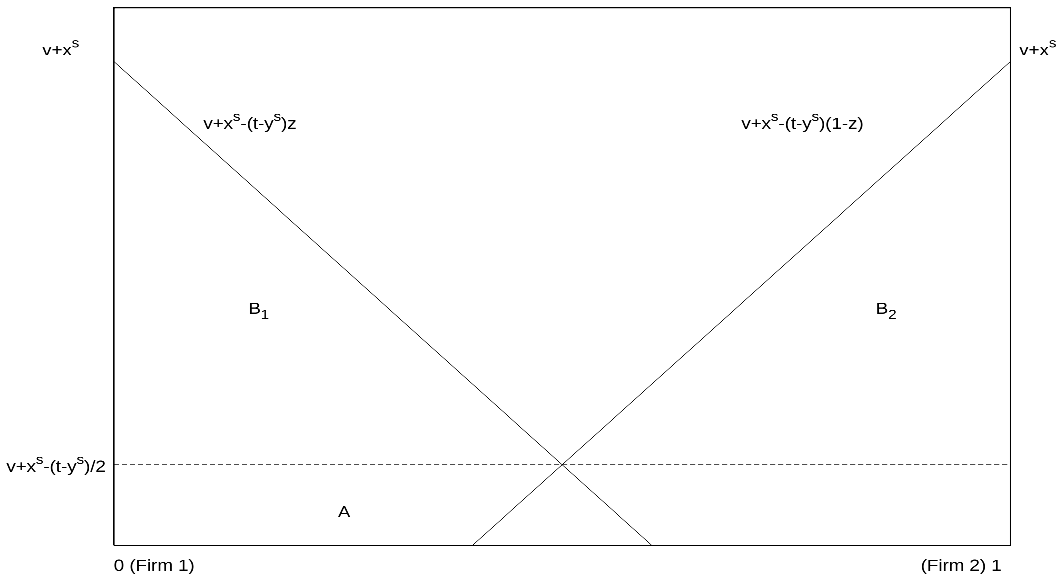


Figure 5: The social welfare is measured by the area under the utility curves. The design changes have different effects for parts $A$ and $B = B_1 + B_2$.

The first order conditions are $(i = 1, 2)$

$$f'(x_i^s) = D_i^s \tag{13}$$

$$g'(y_i^s) = \frac{1}{2} D_i^{s^2} \tag{14}$$

where

$$D_i^s = \bar{D}_i^s(x_1^s, x_2^s, y_1^s, y_2^s) = \frac{x_i^s - x_{-i}^s + t - y_{-i}^s}{2t - y_i^s - y_{-i}^s}.$$

The following proposition lists too important observations about the socially optimal design changes.

*Proposition 8:* The socially optimum product design changes are asymmetric.[22] The optimal designs are more valuable and less specific relative to the status quo.

*Proof:* Asymmetry is similar to the case of RJV. The rest of the proposition follows from the first order conditions. □

At this point I proceed to comparisons of various cases. The symmetric equilibrium design changes of the cases considered in this paper is presented in Figure 1.6, where for clarity of exposition, the prices are ignored and the utility derived from only one firm is provided.

In the symmetric equilibrium, it is unambiguously true that the prices in the cooperative cases are ordered as $p^m > p^{pc}$, and in the competitive cases as $p^{rjv} > p^* > p^{sim}$. Plausible assumptions (such as $v - c - \frac{3t}{2}$ when $f(u) = g(u) = u^2$) guarantee that $p^{pc} > p^{rjv}$, and hence the prices can be ordered as

$$p^m > p^{pc} > p^{rjv} > p^* > p^{sim}.$$

Note that prices decrease with product specificity if price competition is expected, i.e., the price levels are positively correlated with the ability to avoid

[22] Asymmetric social optimum is observed by Salant and Shaffer (1999) in a different context.

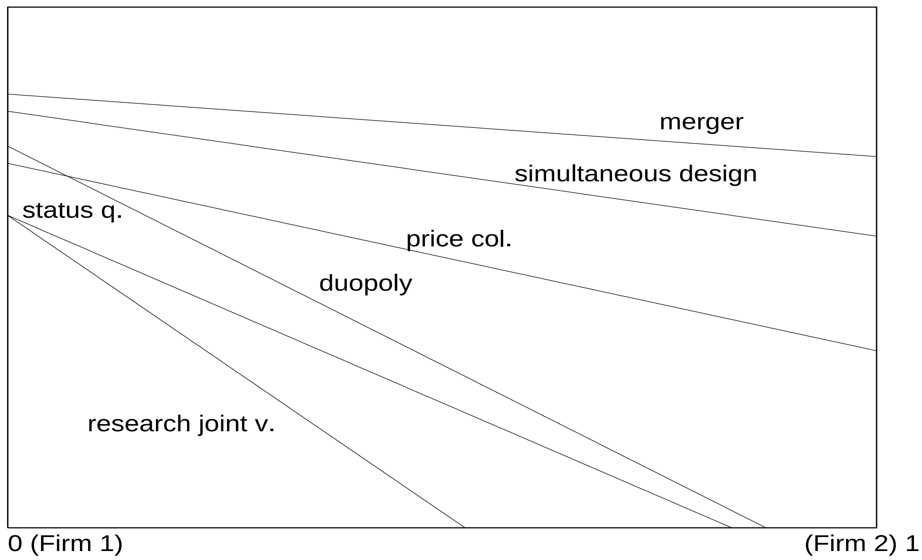


Figure 6: The design changes in the symmetric equilibria.

price competition via more specific designs. In the cases where a form of price collusion is expected, the firms design more valuable and less specific products as long as they can extract the benefits to the marginal consumer in the form of price changes. In the case of merger anticipation, the attempt to increase relative bargaining power also contributes to designing more valuable and less specific products.

Since the market is always covered, the market demand is not downward sloping. Even though social welfare comparisons in this model may not be as interesting as it would be in a model with downward-sloping demand, it is still useful to provide an ordering of cases according to social welfare. In the symmetric case social welfare is given by[23]

[23]For lower levels of convexity of cost functions, asymmetry is possible in the social optimum. A similar phenomenon is observed by Salant and Shaffer (1999).

$$SW = [v + x - c - \frac{t-y}{4}] - 2(f(x) + g(y)).$$

Keeping in mind that as, say, $f(\cdot)$ gets more convex, ${f'}^{-1}(\cdot)$ gets more concave, it is easy to show that the following welfare ordering holds as the functions get more convex (for example $f(u) = g(u) = u^a, a \geq 2$).

$$SW^s > SW^{sim} > SW^m > SW^{pc} > SW^* > SW^{rjv}.$$

Notice that a multi-product monopoly (whether it is the static monopoly, or the post merger multi product monopoly) may provide higher social welfare in this model, relative to the cases that involve price competition. This higher welfare is due to the monopoly's ability to coordinate the pricing structure across its products. Davis, Murphy and Topel (2001) present a similar result. These results show the importance of non-price competition in considerations of social welfare, and particularly in the anti-trust policy.

# 7 Concluding remarks

In this paper, I consider non-price competition in the form of product design changes. First I consider product design incentives under price competition. I model product design changes as strategic responses of firms to different expectations of the probability of successful merger and price collusion. I show that the design incentives in merger or price collusion are drastically different from the incentives in price competition or research joint venture (RJV). Firms increase their product specificities to soften the price competition, and this incentive is reinforced in an RJV. In general, these increases in product specificity decrease the social welfare. On the other hand, the firms that anticipate to collude in prices or to merge decrease product specificity, and do not necessarily decrease social welfare, even though the prices may increase. The paper ends with a ranking of all the cases considered.

I provide an important generalization to the product design changes in the literature via modeling the design changes as both changes in the values and the specificities of the products. The design changes that affect consumer groups differently are modeled using the linear city model by letting each firm invest in two types of design changes: $x_i$ improves the valuation $v$ and $y_i$ decreases the specificity factor $t$ of firm $i$'s product. The design changes are costly, and the respective cost functions $f(x_i)$ and $g(y_i)$ are strictly convex. In addition to the cases of duopoly, RJV, merger and price collusion, I provide several benchmark cases such as the simultaneous design and price competition, monopoly and the social optimum. A ranking of the design changes in symmetric equilibria in these cases is given in Table 1 and Figure 6.

Table 1 Design Changes in the Symmetric Equilibria (ordered by descending specificity)

A strategic design change may target specific groups. Therefore, a design change need not increase or decrease the utility of all the consumers. Without the possibility of merger or price collusion, firms tend to design their products to reward existing customers and penalize customers favoring their rivals. Firms

| **Expectation** | **24f′(x)** | **24g′(y)** |
|---|---|---|
| Research Joint Venture | 0 | −12 |
| Duopoly | 8 | −2 |
| Price Collusion | 6 | 3 |
| Simultaneous Competition | 12 | 6 |
| Merger | 14 | 7 |

attempt to lock-in the customers to soften rival's pricing strategy, leading to overly specific products that are inefficient. If firms collude in the design changes (i.e., form an RJV), then products are even more specific relative to the duopoly. Collusive designs lead to more specific products, and hence to higher prices for the locked-in consumers.

As can be seen from Table 1, anticipation of price competition in duopoly leads to setting $y < 0$, that is, a more specific product than the initial product (i.e., the status quo). These design changes yield higher prices and profits compared to the case of price competition without design changes. Since $x > 0$, each product is valued more, and this may offset the negative effect of the price increase in utility, but this is more likely to happen to the existing consumers, due to the increase in the specificity of the product. Putting it another way, the design change corresponds to a price discount that is greater for the existing customers (or a price increase that is less for them). This kind of a design change is in compliance with the introduction of Frequent Flyer Programs and Super Video CD players that are design changes to lock-in the existing customers. An

RJV enables the firms to design even more specific products due to the same incentive of softening the price competition. Thus, the prices are higher when firms are able to collude in the design stage, and the social welfare is strictly lower.

If firms anticipate a merger with a sufficiently high probability they tend to design less specific products than the status quo and the duopoly. Anticipating a merger is also thought as a way of modeling price collusion where the monopoly profits are shared via a bargaining process. In the bargaining process respective duopoly profits constitute the outside options of the firms. I also present another model of price collusion where firms bargain when the outside option is zero, as opposed to duopoly profits in the case of merger. The design incentives are qualitatively similar to the case of merger anticipation but quantitatively scaled down. In the case of merger anticipation, the value of the merger to the firm, which each firm aims to maximize, is a function of both the post-merger pie to be divided and the difference between the outside options (i.e., the relative bargaining power). As long as the marginal cost of designing a less specific and more valuable product is lower than the benefit to the marginal consumer, the firms can increase their post-merger prices by a corresponding amount, and hence they increase the post-merger pie. The relative bargaining power of a firm increases with more valuable and less specific products since such products pose a greater threat to the competitor if bargaining breaks down. Both the incentive to increase the relative bargaining power prior to the merger, and the incentive to increase the post-merger pie to be divided lead firms to differentiate less and underprovide product diversity.

The design changes with merger anticipation bring a higher utility increase for the consumers that are more likely to buy from the other firm. An interesting example to the case of merger anticipation is the competition between ZDNet and CNET, before CNET acquired ZDNet. Pre-merger competition was characterized by both firms' attempts to target marginal consumers, instead of trying to increase consumer loyalty. This observed behavior is in compliance with the predictions of the present model when a merger is anticipated, as opposed to the case where price competition is expected.

The jump of incentives from specific product designs in duopoly to general purpose ones in (certain) merger anticipation is interesting. As the Lucas Critique prescribes, firms take the policy of Department of Justice (DOJ) with respect to mergers into account. I incorporate the expectation of firms about the DOJ decision to the model as an exogenous commonly known probability of success of merger. Firms tend to decrease product specificity as the probability of merger increases. Hence the competition between CNET and ZDNet prior to their merger is in compliance with this modification of the model when the probability of merger is sufficiently high.

Finally, I compare the outcomes with the socially optimum outcome. Due to the assumption of always serving the whole market, the model does not have a downward sloping demand, which causes the welfare comparisons to be relatively less interesting. Following the efficient solution, social welfare is highest in the cases of simultaneous price and design collusion, followed by the cases of merger anticipation, price collusion, duopoly and design collusion. Although my model does not consider the case of a downward sloping market demand, it shows that firms anticipating a merger or post-merger multi-product monopoly can provide better design incentives relative to price competition.

# A Existence and uniqueness of SPNE (Duopoly and merger)

The first order conditions for the firm's maximization problem in the cases of duopoly and merger can be written in terms of the equilibrium market shares as in the text. Similarly, the Hessians are also easily written in terms of markets shares and the Hessians are similar in structure, too.

Duopoly:

$$\begin{bmatrix} \frac{2}{9(2t-y_1-y_2)} - f''(x_i) & \frac{2}{3(2t-y_1-y_2)}(D_i - \frac{1}{3}) \\ \cdot & \frac{2}{2t-y_1-y_2}(D_i - \frac{1}{3}) - g''(y_i) \end{bmatrix}$$

Merger:

$$\begin{bmatrix} \frac{1}{4(2t-y_1-y_2)} - f''(x_i) & \frac{1}{2(2t-y_1-y_2)}D_i^m \\ \cdot & \frac{1}{2t-y_1-y_2}(D_i^m)^2 - g''(y_i) \end{bmatrix}$$

I assume that the design changes are restricted so that the firms remain in the competitive case, that is, both $D_i$ and $D_i^m$ belong to th interval $(0,1)$ for each firm $i$. Utilizing this assumption, a simple sufficient condition on the level of convexities of cost functions that guarantees the negative definiteness of both of the Hessian matrices above can be written as follows:

$$f''(x_i) > \frac{3}{4(2t - y_1 - y_2)} \quad \text{and} \quad g''(y_i) > \frac{1}{2t - y_1 - y_2}.$$

The symmetric outcome where the market shares are equal to $\frac{1}{2}$ satisfies these constraints, and thus is the unique best response of the firm if

$$f''(x) > \frac{3}{8(t-y)} \quad \text{and} \quad g''(y) > \frac{1}{2(t-y)}$$

where $(x, y)$ can be the equilibrium design changes in duopoly or merger.

When symmetric outcome is the unique best response of each firm the outcome is the unique pure strategy SPNE. (The case of price collusion is similar to the case of merger, and hence is omitted).

A straightforward example where all these conditions hold is the case where $f(u) = g(u) = u^2$. In this case when the market shares are in $(0, 1)$, both Hessians are negative definite if $2t - \frac{1}{2} > y_1 + y_2$. The symmetric outcome is the unique best response if $t > \frac{13}{24}$ and $y_1 + y_2 < \frac{7}{12}$.

# B Research joint venture and asymmetric design changes

If there is no participation constraint (or there is a loose one) then the firms always prefer to set asymmetric design changes, in the sense that either $x_i$'s or $y_i$'s are different. To show this, note that if $x_i = x_{-i} = x$ and $y_i = y_{-i} = y$ for each firm $i$, then the total industry profits (after the design changes are set in the first stage are:

$$\sum \Pi_i^{NE-sym} = \frac{t-y}{2}.$$

Now let $y_i = y_{-i} = y$ for each $i$. Then

$$\sum \Pi_i^{NE-asym} = 2(t-y) \sum (\frac{1}{2} + \frac{(x_i - x_{-i})}{6(t-y)})^2.$$

Comparing the symmetric and asymmetric profits, it is clearly seen that if $y_i = y$, then $x_i = x_{-i}$ never maximize the total industry profits.

# C Proof of Proposition 3

It is conceivable at the outset that the centralized management has the option to operate both firms or shut down one of them before deciding on the price(s). By Lemma 6 below however, shutdown is ruled out.

*Lemma 6:* The centralized firm always profits more when the firms operate as local monopolies compared to the case when one of the firms is shut down.

*Proof:* Note that, the firms can always increase prices to operate as local monopolies leaving the middle part of the market uncovered. The merged firm's total profit in this case is

$$\pi^{m^{local}} = \sum_{i=1}^{2} (p_i - c) \frac{v + x_i - p_i}{t - y_i}$$

Now, assume without loss of generality that firm $-i$ is shut down. Then the monopoly behavior can be found by maximizing $\pi_i^{local}$, which yields the optimal price and market share as, respectively, $\frac{v+x_i+c}{2}$ and $\frac{v+x_i-c}{2(t-y_i)}$. Obviously, this case renders a different aspect of the problem only if it is optimal for firm

$i$ to cover all of the market, because otherwise it is always more profitable to operate the other firm as a local monopoly in the uncovered part of the market and profit more. Thus, assume $\frac{v+x_i-c}{2(t-y_i)} \geq 1$, which guarantees market coverage as a result of the optimal market share. In this case price is increased so long as the whole market is barely covered, thus the shut down price is defined by $x + x_i - p_i^{*shutdown} - (t - y_i) = 0$ and the profit equals $v + x_i - c - (t - y_i)$. Now it can easily be shown that there exists and $\epsilon > 0$ $p_{-i}$ such that

$$v + x_i - c - (t - y_i) + \epsilon \frac{v + x_i - (v + x_i - (t - y_i) + \epsilon}{t - y_i} + \frac{v + x_i - p_{-i}}{t - y_i}(p_{-i} - c) > v + x_i - c - (t - y_i),$$

is always true, so I rule out the case of shutting down one firm. □

Now the question boils down to a comparison of competitive and the local monopoly cases. Allowing firms' markets to overlap, the central management's problem is

$$max_{p_i,p_{-i}} \Pi^{m^{comp}} \quad \text{s.t} \quad \sum_{i=1}^{2} \frac{v + x_i - p_i}{t - y_i} \geq 1$$

where

$$\Pi^{m^{comp}} = [\sum_{i=1}^{2}(p_i - c)\frac{(p_{-i} - x_{-i}) - (p_i - x_i) + t - y_{-i}}{2t - y_i - y_{-i}}]$$

Assuming that it is not profitable to operate the firms as local monopolies, i.e., $\sum \frac{v+x_i-c}{2(t-y_i)} \geq 1$, I proceed to the proof of the proposition. (Note that in the symmetric case this assumption becomes, $v - c - t \geq -x - y$). The first order conditions reveal that

$$\frac{\partial \Pi^m(p_1, p_2)}{\partial p_1} + \frac{\partial \Pi^m(p_1, p_2)}{\partial p_2} = 1. \tag{15}$$

Hence from (B.1), it can be seen that at least one derivative needs to be positive. Thus the centralized firm prefers to cover the market at most barely because at least one of the derivatives is positive, and the price(s) giving positive derivative(s) will be increased by the central management. (Another option could be shutting down one firm when one of these derivatives is non-positive. However this option is ruled out by Lemma 6). □

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