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Marketing Science, Vol. 17, No. 2 (1998), 156-169.

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Product Line Design for a Distribution Channel

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Abstract

When designing a product line, a manufacturer is often aware that it does not control the ultimate targeting of the products in the line to the different consumer segments. While the manufacturers can attempt to influence the target customers through communications in appropriate media, product design, and the choice of channels of distribution, the ultimate targeting is made by a retailer, which might only care about its own interests, and is fully in control of interactions with customers, including how the product is sold and displayed. This occurrence is widespread in numerous markets, for example, frequently purchased consumer products, home appliances, personal computers, automobiles, etc. The audience for this paper includes practitioners and academics who want to better understand how a manufacturer selling through an intermediary can better induce this intermediary to have a targeting strategy consistent with the manufacturer's intentions and be willing to carry the full product line.

The paper attempts to find what are the main issues a manufacturer selling through a distribution channel has to worry about when designing the product line. The problem of the product line design for a distribution channel is modeled with the manufacturer, the retailer or several competing retailers, and the consumers. In this way all the three levels of the distribution system are included.

The model can be summarized as follows. The manufacturer decides how many products to have in the line and the physical characteristics of each product, quality. Each product may or may not be targeted at a different market segment. The manufacturer decides as well how many market segments to try to target and the prices to charge the retailer for each type of product. Given the product line being offered by the manufacturer, the retailer (or competing retailers) decides which products to carry, the market segments that are going to be targeted, which product to target to each segment, and the prices being charged the consumers for each product.

The consumer market is composed of different market segments that value quality differently: Some market segments are willing to pay more for quality than other market segments. The paper presents the results for two market segments, but a greater number of market segments can also be

accounted for. We characterize the equilibrium targeting strategies of the manufacturer and retailer (or competing retailers) in terms of number of products in the line, the physical characteristics of each product, the prices charged by the manufacturer for each product, the consumer prices charged by the retailer for each product, and the product bought by each market segment. We compare the results with the coordinated channel outcome, where the manufacturer and the retailer work together to maximize the overall channel profits. The results are related to the other coordination problems previously studied in the literature (for example, the standard "double marginalization" effect of higher prices reducing demand) in the sense that the retailer makes decisions caring only about its own profits and not the overall channel profits.

The paper shows that, if possible, the best strategy for the manufacturer is to increase the differences in the products being supplied (in comparison to the direct selling/coordinated channel case). If the manufacturer is not able to increase these differences, it then elects to price the product line such that some of the consumer segments end up not being served. The intuition for this result is that the manufacturer, by increasing the differences among the different products, is still making major profits on the high end segments, while getting some positive profits from the low end segments and guaranteeing that the retailer actually targets the different products to the consumer segments intended by the manufacturer. Were the manufacturer not to increase the differences among the different products being offered, the retailer would only target the higher end consumer segments, because also targeting the lower end segments would involve losing too many rents on the higher end segments. Another way of seeing the problem is that the channel pricing distortions increase the cannibalization forces across the product line. The manufacturer tries to compensate for this by increasing the product differentiation across the line. If increasing the differences among the different products being offered is not possible, the manufacturer then drops the low end consumer segments and concentrates on the high end of the market (which is more profitable). The unit margins of both the retailer and manufacturer are also shown to be increasing with the quality level of the product.

(Product Line; Distribution Channels; Product Policy; Pricing; Segmentation)

1. Introduction

When designing a product line, a manufacturer is often aware that it does not control the ultimate targeting of the products in the line to the different consumer segments. While the manufacturers can attempt to influence the target customers through communications in appropriate media, product design, and the choice of channels of distribution, the ultimate targeting is made by a retailer, which might only care about its own interests, and is fully in control of interactions with customers, including how the product is sold and displayed. This occurrence is widespread in numerous markets, for example, frequently purchased consumer products, home appliances, personal computers, automobiles, etc. The product line can be composed of products of different qualities or just different package sizes. Consider the personal computers case: When IBM designs its product line it has to be aware that the ultimate targeting of the products in the line is made by the retailers; on the other hand, Dell, when designing its line and selling direct, has a greater control on the targeting process.

Similarly, as suggested above, the tensions of selling a product line through a distributor are well documented in the automobile industry, by the bargaining between dealers and manufacturers about the appropriate mix of products (which reflects the appropriate targeting) that should be carried by the dealers: The dealers want to carry the "fast-selling" automobiles and drop the "hard-to-market" models. These classifications obviously depend on the dealer's intended targeting strategies. For example, in *Maxfield v. AMC* (1981) it is noted that AMC may have forced the dealer (Maxfield) to carry the large "hard-to-market" cars (Ambassadors and Matadors) in return for carrying the small "fast-selling" models (Gremlins and Hornets).¹

In general, the manufacturer has to design the product line such that the retailer wants to carry the full line and is willing to target each product in the line to

the segment intended by the manufacturer. The retailer considers the products supplied by the manufacturer and its intermediate prices, decides which products to carry, and which consumer segments to sell to. The manufacturer, aware of the retailer behavior, may then choose among different strategies to better influence the retailer's discretion.² One possibility is to limit the retailer's discretion by reducing the number of products available to the retailer. This alternative would tie the retailer's hands by not allowing it to play with targeting different products to different consumer segments. On the other hand, the definite drawback of this alternative is that the whole channel would then not segment the market as well, with different consumer segments ending up buying the same product or not buying at all. Another alternative would be for the manufacturer to increase the differences among the products supplied to the retailer (or increase the length of the product line) in order not to allow the retailer to play with the manufacturer's intended targeting of the different products to the different consumer segments. This alternative would still allow the whole channel to segment the market completely. The major drawback is that it would result in a greater distortion of the products that end up being purchased by the different segments.

This paper shows that, if possible, the best strategy for the manufacturer is actually the latter alternative, i.e., to increase the differences in the products being supplied (in comparison to the direct selling case). If the manufacturer is not able to increase these differences, it then elects to price the product line such that some of the consumer segments end up not being served. The intuition for this result is that the manufacturer, by increasing the differences among the different products, is still making major profits on the high end segments, while getting some positive profits from the low end segments and guaranteeing that the retailer actually targets the different products to the consumer segments intended by the manufacturer. Were the manufacturer not to increase the differences among the different products being offered, the retailer would only target the higher end consumer segments, because also targeting the lower end segments would

¹*Bob Maxfield, Inc. v. American Motors Corporation*, 637 F. 2d 1033 (5th Cir. 1981). Another interesting example of these tensions at work is *Southern Pines Chrysler-Plymouth, Inc. v. Chrysler Corporation*, 826 F. 2d 1360 (4th Cir. 1987) where it is also noted that Chrysler Corporation may have forced the dealer (Southern Pines) to carry "hard-to-market" models.

²Strategies that involve restraints of trade are discussed in the §4.

involve losing too many rents on the higher end segments. Another way of seeing the problem is that the channel pricing distortions increase the cannibalization forces across the product line. The manufacturer tries to compensate for this by increasing the product differentiation across the line. If increasing the differences among the different products being offered is not possible, the manufacturer then drops the low end consumer segments and concentrates on the high end of the market (which is more profitable). The unit margins of both the retailer and manufacturer are also shown to be increasing with the quality level of the product. The results are shown in §3.

There are two main literatures related to this paper: the literature on coordination and conflict in a channel and the literature on product line design. In relation to the former, this paper can be seen as identifying a new form of coordination problem in a channel, namely, the lack of coordination on the product line being supplied. This effect is to be added to the list of coordination problems currently identified in a monopoly setting (or in a setting where both manufacturers and retailers have market power). The relation of the results presented here to the coordination literature is discussed in greater detail in §4. This new effect seems to be particularly important given that most manufacturers sell a product line (several products) rather than a single product. Furthermore, the real world is full of stories of conflict between manufacturers and retailers about the product line that the retailers are willing to carry.

There is also a long literature on product line design with a seller facing different consumer segments (e.g., Mussa and Rosen 1978; Moorthy 1984; Oren, Smith, and Wilson 1984; Reibstein and Gatignon 1984; Shugan 1984; Dolan 1987; Gerstner and Hess 1987; Dobson and Kalish 1988; Balachander and Srinivasan 1994; Zenor 1994). This paper is closer in spirit to Mussa and Rosen (1978) and Moorthy (1984) in the sense that it looks at a product line, where the preference ordering for the products in the line is the same across different consumer segments. The seller then designs the product line and prices it such that the different consumer segments choose different products. Mussa and Rosen and Moorthy consider the case of a seller selling directly a product line, while this paper looks at a manufacturer selling a product line through a retailer. The

manufacturer designs the product line and sets intermediate prices for each product. The retailer then, using the product line specified by the manufacturer and the intermediate prices for each product, decides which products to carry, the pricing for each product to the final consumers, and the target segment for each product. Shugan and Desiraju (1995) also look at the retailer pricing of a line that was specified by the manufacturer, without analyzing the product line design problem and without starting from the relative preferences of the different segments.

The rest of paper is organized as follows. In the next section, the general framework for the analysis is presented. Section 3 presents the results. Section 4 discusses in detail the relation of the results presented here to the channel coordination literature and several marketing implications and extensions of the results (in particular, extensions to richer institutional settings). Section 5 concludes.

2. The Model

To study the problem of product line design in a distribution channel, consider the following framework. Different products are identified by different quality levels, q . Consumer segments are identified by θ , a parameter that indicates the relative preference for quality. The relative size of the different segments is defined by the cumulative distribution function on θ , $F(\theta)$. To concentrate on the product line design problem, the consumers with a relative preference for quality θ have exactly the same preferences, either all buy a product or do not buy it. Allowing for consumers with the same preference for quality to have overall different preferences can be done (without changing the main message of the results presented here) and results in downward sloping demand functions for each θ , with the well-known "reduced demand due to higher prices" effects in a channel.³

The retailer charges potentially different prices for different products: The retailer price of a product with quality q is denoted by $p(q)$. The ultimate targeting decided by the retailer is then modeled here by the retailer's choice of the pricing schedule $p(q)$. In general,

³Some analysis on this generalized problem is available upon request from the author.

the ultimate targeting decided by the retailer may involve also advertising, promotion, or service strategies. One might interpret the model presented here as summarizing all these dimensions of targeting into the pricing dimension or as considering only the pricing dimension of the retailer targeting strategy. The manufacturer also charges the retailer potentially different prices for different products: The manufacturer price of a product with quality q is denoted by $w(q)$.

The overall utility of a consumer belonging to segment θ and purchasing a product with quality q is $U(\theta, q) = V(\theta, q) - p(q)$, where $V(\theta, q)$ is the gross utility. As is typical (see, for example, Moorthy 1984) $V_\theta > 0$, the utility is higher for a consumer with a higher relative preference for quality;⁴ $V_q > 0$, the gross utility is higher with a product of higher quality; $V(\theta, 0) = 0 \forall \theta$, a product with zero quality yields no gross utility; and $V_{\theta q} > 0$, the sorting condition, consumers with a higher relative preference for quality enjoy more an increase in the quality of a product. If a consumer (for any segment) does not purchase any product (s)he gets a utility of zero. We refer to the consumer segments that value quality more as the *high end segments* and to the consumer segments that value quality less as the *low end segments*. As seen below, in equilibrium the consumers from the high end segments purchase the high end products (higher quality products), and the consumers from the low end segments purchase the low end products (lower quality products).

The retailer's only costs are the prices paid to the manufacturer. The profit for the retailer of selling one product with quality q is then $p(q) - w(q)$. The manufacturer incurs a cost of $C(q)$ for producing one unit of a product of quality q , where $C'(q) > 0$, it is more costly to produce products of greater quality, and $C''(q) > 0$, producing products of greater quality is more and more costly. The profit for the manufacturer of selling a product with quality q is then $w(q) - C(q)$. The manufacturer is not able to either charge a fixed fee or to enforce a contract requiring that the retailer buys a fixed proportion of the products in the product line for

reasons outside the model. This is consistent with the approach taken in some of the existing channel coordination literature (e.g., Gerstner and Hess 1995). It could be justified by the following type of argument, as suggested by Rao and Srinivasan (1997) in the context of franchising. The manufacturer and the retailer are in an ongoing relationship where there is variation through time of the demand and cost conditions. In this environment and if there are significant costs for the manufacturer and retailer to rewrite the contract that governs their relationship every time the demand and cost conditions change, then the optimal contract may be the uniform pricing contract (without fixed fee or fixed proportion of products in the product line). Alternatively, the argument could have to do with being impossible to specify *ex ante* the characteristics (due to their infinite number) of the products that are valued by the consumers and with the inability of the retailer and manufacturer to commit not to renege.

The sequence of actions is as follows. The manufacturer decides first the product line design (the number of products in the line and the quality of each product) and the prices for each of the products in the line to be paid by the retailer. The retailer then considers the product line supplied by the manufacturer and the manufacturer price associated to each product, and decides which products in the line it will carry and the price for each of these products that a consumer buying that product would have to pay. Finally, each consumer looks at the products carried by the retailer and the prices being asked, and chooses to buy one of the products or none.

3. The Results

Consider the simple case in which the market is composed of only two segments.⁵ The low end segment has a relative preference for quality denoted by $\underline{\theta}$ and its fraction of the market is denoted by γ . The high end segment has a relative preference for quality denoted by $\bar{\theta} > \underline{\theta}$, and its fraction of the market is $1 - \gamma$. The analysis will proceed as follows. First, the product line design for the case where there is no retailer is presented (the coordinated channel case). Second, to better illustrate the forces at work, I consider the case in

⁴Throughout the paper the partial derivative of a function F with respect to its argument x will be denoted by F_x . For functions of only one variable, derivatives will be denoted by a prime, i.e., $dF(x)/dx = F'(x)$.

⁵For the case of a continuum of segments, check Villas-Boas (1996).

which the manufacturer maintains the product line of the coordinated case and evaluate the retailer's behavior. Finally, the manufacturer is allowed to change the product line to adjust for the subsequent retailer actions.

3.1. The Coordinated Channel

The set up for the coordinated channel case can be directly obtained from the existing literature (for example, Moorthy 1984). The channel wants to maximize its profits while making sure that each consumer segment buys the product that (s)he is supposed to buy (incentive compatibility constraints), and that each consumer segment that is supposed to buy a product actually chooses to do so (individual rationality constraints). Denoting \underline{p} and \underline{q} as the price and quality of the product intended to the low end consumer segment (i.e., $\underline{\theta}$) and \bar{p} and \bar{q} as the price and quality of the product intended to the high end consumer segment (i.e., $\bar{\theta}$), we know that the binding incentive compatible and individual rational constraints yield the price of the low quality product, $\underline{p} = V(\underline{\theta}, \underline{q})$, and the price of the high quality product, $\bar{p} = V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q})$. In terms of product qualities, it can also be obtained directly from the existing literature that the coordinated channel product line has two products with qualities \underline{q}^c and \bar{q}^c satisfying

$$V_q(\bar{\theta}, \bar{q}^c) = C'(\bar{q}^c), \tag{1}$$

$$V_q(\underline{\theta}, \underline{q}^c) = C'(\underline{q}^c) + \frac{1-\gamma}{\gamma} [V_q(\bar{\theta}, \underline{q}^c) - V_q(\underline{\theta}, \underline{q}^c)]. \tag{2}$$

Equation (1) is the standard result that the quality level of the product targeted to the high end segment is the efficient one (as if the channel were able to identify the segment of each consumer). Equation (2) is also the standard result that the quality level of the product targeted to the low end segment is lower than the efficient one. This is because $V_q(\bar{\theta}, \underline{q}^c) - V_q(\underline{\theta}, \underline{q}^c) > 0$ (given $V_{\theta\theta} > 0$). The prices of the two products would then be $\bar{p}^c = V(\bar{\theta}, \bar{q}^c) - V(\bar{\theta}, \underline{q}^c) + V(\underline{\theta}, \underline{q}^c)$ and $\underline{p}^c = V(\underline{\theta}, \underline{q}^c)$.⁶

⁶Note also that these would be the manufacturer prices and qualities offered in a world in which there was an intermediary who was able to perfectly price discriminate between consumers.

3.2. Optimal Retailer Behavior with a Naive Manufacturer

Let us now introduce an optimizing (and independent) retailer. Suppose first that the manufacturer behaves as in the coordinated channel case. It is important to consider the case of the naive manufacturer because it illustrates the type of problems the manufacturer might incur if it does not adjust its product line design to the existence of an intermediary. In addition, looking at the naive manufacturer case gives some intuition for the case in which the manufacturer and retailer act strategically.

In the naive manufacturer case we then have that the quality levels and wholesale prices of the products sold by the manufacturer are the same as the coordinated channel case quality levels and prices, i.e., $\underline{q} = \underline{q}^c$, $\bar{q} = \bar{q}^c$, $\underline{w} = \underline{p}^c$, and $\bar{w} = \bar{p}^c$, denoting \underline{w} and \bar{w} as the manufacturer prices for the products targeted, respectively, to the low and high end segments.

Consider now uncovering the retailer best strategy: which products to carry and what prices to set. The retailer has three basic options: carry both products, carry only the low quality product, or carry only the high quality product. If it decides to carry both products, it has zero profits because the price of the low quality product, \underline{p} , has to be lower or equal to the gross utility obtained by the low end segment consumers, $V(\underline{\theta}, \underline{q}^c)$, and the price of the high quality product, \bar{p} , has to be lower or equal to $V(\bar{\theta}, \bar{q}^c) - V(\bar{\theta}, \underline{q}^c) + \underline{p}$ for the high end consumers to prefer to buy the high quality product. The best pair of prices that satisfies these two constraints is $\underline{p} = \underline{w}$ and $\bar{p} = \bar{w}$, i.e., they yield zero profits.

If the retailer decides to carry just the low quality product it gets a profit of

$$(1 - \gamma)[V(\bar{\theta}, \underline{q}^c) - V(\underline{\theta}, \underline{q}^c)] > 0$$

because it can charge a price equal to $\underline{p} = V(\underline{\theta}, \underline{q}^c)$ and target only the high end segment.

If the retailer decides to carry just the high quality product it gets at most a profit of

$$\begin{aligned} &(1 - \gamma)[V(\bar{\theta}, \bar{q}^c) - [V(\bar{\theta}, \bar{q}^c) - V(\bar{\theta}, \underline{q}^c) + V(\underline{\theta}, \underline{q}^c)]] \\ &= (1 - \gamma)[V(\bar{\theta}, \underline{q}^c) - V(\underline{\theta}, \underline{q}^c)] \end{aligned}$$

because the retailer will set $\bar{p} = V(\bar{\theta}, \bar{q}^c)$.

That is, the retailer will only sell one product and is indifferent between selling the low or the high quality one. In both cases, the retailer sells only to the high end segment.⁷ The indifference of the retailer between selling the high and the low quality product comes from the optimal design of the product line in the coordinated channel: the high end segment is made indifferent between buying the high and the low end product. These results are summarized in the following proposition.

PROPOSITION 1. *In the case of a naive manufacturer, the retailer chooses to sell only to the high end segment. If there are only two market segments, the retailer is indifferent between selling the high or the low quality product.*

The manufacturer would prefer that the retailer would sell the high quality product because then the manufacturer profit would be

$$(1 - \gamma)[V(\bar{\theta}, \bar{q}^c) - V(\bar{\theta}, q^c) + V(\underline{\theta}, q^c) - C(q^c)],$$

which is greater than its profit if the retailer chose to sell the low quality product, which is $(1 - \gamma)[V(\underline{\theta}, \underline{q}^c) - C(\underline{q}^c)]$.

3.3. Product Line Design in a Channel

Consider now the case in which the manufacturer designs the product line taking into account the retailer behavior. Consider first the retailer optimal pricing and targeting strategies. Intuitively, if either of the products has too high a manufacturer price, the retailer will not carry that product. If the manufacturer prices of the two products are very different, the retailer carries only the low quality product (the one with the lower price). Similarly, if the manufacturer prices of the two products are very close, the retailer carries only the high quality product.

To check analytically these conditions note that if the retailer carries both products its profit is (using the results above)

$$\gamma[V(\underline{\theta}, q) - \underline{w}] + (1 - \gamma)[V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, q) + V(\underline{\theta}, q) - \bar{w}].$$

⁷As seen in Villas-Boas (1996), the result of the retailer indifference between carrying the high and the low quality product is not robust to a specification with more consumer segments. In the general case, the retailer decides not to carry some of the lower quality products.

If the retailer carries only the low quality product and sells it to both segments, it gets a profit equal to $V(\underline{\theta}, q) - \underline{w}$. The condition that the retailer prefers to carry both products to carrying just the low quality brand (targeted to both segments) can then be written as

$$\bar{w} - \underline{w} \leq V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, q), \quad (3)$$

i.e., the two manufacturer prices cannot be too different.

Similarly, if the retailer decides to carry only the high quality product and targets it only to the high end segment it can get a profit equal to $(1 - \gamma)[V(\bar{\theta}, \bar{q}) - \bar{w}]$. The condition that the retailer prefers to carry both brands to carrying just the high quality brand (targeted to the high end segment) can then be written as

$$\underline{w} \leq \frac{V(\underline{\theta}, q) - (1 - \gamma)V(\bar{\theta}, q)}{\gamma}, \quad (4)$$

i.e., the manufacturer prices cannot be too high.

Noticing that if the manufacturer wants a product line with just one product, it will then set $q = 0$, one still has to consider two other conditions to make sure that the retailer carries both products: the retailer prefers to carry both products to carrying only the low quality product targeted only at the high end segment,⁸ and the retailer prefers to carry both products to carrying only the high quality product targeted at both segments.⁹ It turns out that, in equilibrium, these conditions are not binding, and the only binding conditions are represented by equations (3) and (4).

PROPOSITION 2. *In the two market segments case and a strategic manufacturer, the retailer decides to target both segments with different products if the difference in manufacturer prices is not too large and if the manufacturer prices are not too high. The binding incentive compatibility constraints for the retailer are (i) that it prefers targeting both segments with different products to targeting both segments with the low quality product, and (ii) that it prefers targeting*

⁸This condition is $\gamma[V(\underline{\theta}, q) - \underline{w}] + (1 - \gamma)[V(\bar{\theta}, \bar{q}) - 2V(\bar{\theta}, q) + V(\underline{\theta}, q) - \bar{w} + \underline{w}] \geq 0$, which is implied by conditions (3) and (4).

⁹This condition is $\bar{w} - \underline{w} \geq V(\underline{\theta}, q) - V(\underline{\theta}, \bar{q})$. Note that it can be jointly satisfied with condition (3). Note also that in equilibrium this condition will not be binding because then the manufacturer can increase its profits by raising the manufacturer price of the high quality product.

both segments with different products to targeting only the high end segment with the high quality product.

The manufacturer problem is then to design the product line to maximize its profits subject to constraints (3) and (4), the conditions that guarantee that the retailer wants to carry both products, and to the nonnegativity constraints on the quality levels. Analytically,

$$\max_{\underline{w}, \bar{w}, \underline{q}, \bar{q}} \gamma[\underline{w} - C(\underline{q})] + (1 - \gamma)[\bar{w} - C(\bar{q})], \quad (5)$$

$$\text{s.t. } \bar{w} - \underline{w} \leq V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}), \quad (6)$$

$$\underline{w} \leq \frac{V(\underline{\theta}, \underline{q}) - (1 - \gamma)V(\bar{\theta}, \underline{q})}{\gamma}, \quad (7)$$

$$\underline{q} \geq 0, \bar{q} \geq 0. \quad (8)$$

Given that conditions (6) and (7) are binding and substituting for \underline{w} and \bar{w} (the manufacturer prices for the lowest and highest quality being offered) in the objective function, forgetting about the nonnegativity constraints on the quality levels, differentiating the objective function with respect to the quality levels \underline{q} and \bar{q} and equalizing to zero, one obtains the equilibrium product line design, \underline{q}^* , and \bar{q}^* , the lowest and highest qualities offered by the manufacturer, as satisfying

$$V_q(\bar{\theta}, \bar{q}^*) = C'(\bar{q}^*), \quad (9)$$

$$V_q(\underline{\theta}, \underline{q}^*) = C'(\underline{q}^*) + \frac{1 - \gamma^2}{\gamma^2} [V_q(\bar{\theta}, \underline{q}^*) - V_q(\underline{\theta}, \underline{q}^*)]. \quad (10)$$

Note that $\bar{q}^* = \bar{q}^c$, i.e., the high end segment is still getting the efficient quality level. However, $\underline{q}^* < \underline{q}^c$ (because $(1 - \gamma^2)/\gamma^2 > (1 - \gamma)/\gamma$), i.e., the manufacturer decides now to have a more distorted product line than in the coordinated channel case. This is because the manufacturer takes into account the retailer profit maximizing behavior and realizes that to target the different segments, the product line has now to be extended (a greater difference between the products in the line). The manufacturer, by increasing the differences among the different products, is still making major profits on the high end segments while getting some positive profits from the low end segments and

guaranteeing that the retailer actually targets the different products to the consumer segments intended by the manufacturer. Were the manufacturer not to increase the differences among the different products being offered, the retailer would only target the higher end consumer segments, because also targeting the lower end segments would involve losing too many rents on the higher end segments. In other words, the manufacturer has to distort its quality levels downward to better take into account the retailer's behavior (and the adjustment of the product line is not just through prices). Note also that, because the lowest quality being offered is smaller than in the coordinated channel, $\underline{q}^* < \underline{q}^c$, the nonnegativity constraint on the quality level of the product targeted to the low end consumer segment might now be binding, whereas it might not have been under channel coordination. If this is the case, the existence of the retailer makes now the manufacturer shorten its product line (the product line has only one product), and only target a product to the high end segment.¹⁰

PROPOSITION 3. *In the two market segments case and a strategic manufacturer, the product line chosen by the manufacturer is more distorted than in the coordinated channel case. The high end segment is targeted a product with the efficient quality level. The optimal distorted level of the low quality product might involve the manufacturer shortening the product line and not targeting the low end segment.*

The manufacturer prices in equilibrium are equal to

$$\underline{w}^* = \frac{V(\underline{\theta}, \underline{q}^*)}{\gamma} - \frac{1 - \gamma}{\gamma} V(\bar{\theta}, \underline{q}^*)$$

and

$$\bar{w}^* = V(\bar{\theta}, \bar{q}^*) - \frac{V(\bar{\theta}, \underline{q}^*) - V(\underline{\theta}, \underline{q}^*)}{\gamma}$$

¹⁰This can also be seen as the "reduced demand due to higher prices" effect at work in the sense that the existence of the intermediary reduces the quantity being sold. As shown in Villas-Boas (1996), this result is not robust to a specification with a continuum of consumer segments: The manufacturer may still target fewer consumer segments, but it will never reduce the product line.

The retailer equilibrium prices are $\underline{p}^* = V(\underline{\theta}, \underline{q}^*)$ and $\bar{p}^* = V(\bar{\theta}, \bar{q}^*) - V(\bar{\theta}, \underline{q}^*) + V(\underline{\theta}, \underline{q}^*)$. Note that the unit retailer margins for each product end up being the same, i.e., $\bar{p}^* - \bar{w}^* = \underline{p}^* - \underline{w}^* = 1 - \gamma/\gamma [V(\bar{\theta}, \underline{q}^*) - V(\underline{\theta}, \underline{q}^*)]$.¹¹

Note also that while the consumers of the low end segment have the same net surplus as in the coordinated channel case (i.e., zero), the consumers of the high end segment are now worse off because the product they buy has the same quality level as in the coordinated channel case (i.e., the efficient one) and the price they pay is now higher (because the lowest quality offered is smaller than in the coordinated channel, $\underline{q}^* < \underline{q}^c$).

PROPOSITION 4. *In the two market segments case and a strategic manufacturer, the retail margins are the same for both products in the product line. The high end consumers are worse off than in the coordinated channel. The low end consumers have zero surplus in both cases.*

4. Marketing Implications and Extensions

This paper shows that without a coordinated channel, a manufacturer should increase the length of its product line in order to take into account the targeting strategy of the retailer. The different consumer segments will now be targeted with products with less quality than if the channel were perfectly coordinated, and they end up worse off. Failure for a manufacturer to account for the optimal retailer targeting strategies results in the retailer just targeting the higher end consumer segments. In addition to this general marketing implication, one can consider how this general recommendation would be affected with several extensions of the model or of the enlargement of the set of marketing strategies available to the firm. The relation to the results in the existing literature on channel coordination is also presented.

¹¹As seen in Villas-Boas (1996), this result is not robust to a greater number of consumer segments. With a greater number of segments the retail margins are smaller for the products in the line that have lower quality (after the product with the second highest quality level).

Relation to Channel Coordination Literature

The results presented in this paper show another form of lack of coordination in a monopoly setting. The existing literature, as noted in Tirole (1988, pp. 174–181), identifies three main coordination problems: “reduced demand due to higher prices” (e.g., Spengler 1950, Jeuland and Shugan 1983, Moorthy 1987, Gerstner and Hess 1995), “service externalities” (e.g., Lal 1990), and “input substitution” (e.g., Vernon and Graham 1971). These three effects have been widely studied in the existing literature.

Following the definitions in Tirole (1988), the “reduced demand due to higher prices” effect says that because of retail margins over manufacturer margins the retail price ends up being too high, resulting in the quantity sold on a single product being smaller. In Spengler (1950), Tirole (1988), and others, this effect is also labeled “double marginalization.” The “service externalities” effect says that the retailer and/or the manufacturer end up providing less service than is optimal for the channel because they are not the full residual claimants of the channel margin (the retailer gets $p - w$, the manufacturer gets $w - c$, while the channel margin is $p - c$). The “input substitution” effect says that a monopolist retailer buying several inputs will substitute away from the inputs that are supplied through a monopolist.

The effect presented in this paper says that because the retailer has different targeting objectives than the manufacturer, the manufacturer should widen its product line. This new effect is closely related to the effects that had been previously identified in the literature and, in particular, to the traditional double marginalization effect. These four coordination effects are due to the fact that the retailer when making decisions does not take into account the total channel profit but only its own profit. Said differently, the retailer is not the full residual claimant of the organization, i.e., in a setting where there is retailer and manufacturer market power, the retailer margin is set over the manufacturer margin. If there is perfect competition among manufacturers, these four distortions go away because the retailer becomes the residual claimant of the organization. If there is perfect competition among retailers, and even though each retailer is not the residual claimant of the organization, the market

discipline makes the retailers take the coordinated channel decisions in both the "reduced demand due to higher prices" and the "product line distortion" effects.¹²

Note also that the result presented here is somewhat analogous to the "reduced demand due to higher prices" effect in the sense that here we obtain a decrease in the quality level of the low quality product, while in the "reduced demand due to higher prices" effect one obtains a decrease in the quantity demanded. The mechanisms that make these effects work can, however, be seen as quite different: In the "reduced demand due to higher prices" effect, the margins over margins cause the retail price to be too high, resulting in lower demand. In the effect identified in this paper, the possibility of the retailer not willing to carry all the product line and only targeting the high end segments at a very high price makes the manufacturer decrease the quality of the low quality product.

The results in this paper are also related to Gerstner and Hess (1995), who consider the case of targeted pull strategies. Gerstner and Hess show that targeted pull improves the channel profits. The relation of the Gerstner and Hess model to this paper is that targeted pull can also be interpreted as a product line being sold through a channel: Some segments are targeted the product with coupon (lower price, but cost of handling the coupon) and other segments are targeted the product without coupon (higher price, but not costs of handling the coupon). However, the context of that model does not fully allow for an analysis of the optimal design of the product line (with and without an intermediary).

Perfect Competition Between Retailers

One important issue to consider is that in most markets there may exist some degree of competition at the retail level. This competition may undoubtedly introduce important new effects.

At the extreme of retailer perfect competition in all the product line, the retailer prices are, obviously, equal to the prices charged by the manufacturers (given the assumption of zero retail costs), i.e., $\bar{p} = \bar{w}$

and $\underline{p} = \underline{w}$. Then, the manufacturer is able to get the coordinated channel outcome as presented in §3.

More interestingly, note that even if the manufacturer chooses to distribute one product type per retailer, it is still able to achieve the coordinated channel outcome. Suppose one retailer carries only the high quality product, another retailer carries only the low quality product, and these two retailers are in perfect competition. Suppose also that the prices and quality levels set by the manufacturer are as in the coordinated channel, i.e., $\underline{w} = \underline{p}^c$, $\bar{w} = \bar{w}^c$, $\underline{q} = \underline{q}^c$, and $\bar{q} = \bar{q}^c$. Suppose now that the retailer that carries the low quality product charges a price $\underline{q} = \underline{w}$. Then, a best response for the retailer carrying the high quality product is charging a price $\bar{p} = \bar{w}$ because any price above \bar{w} would yield no demand. In the same way, suppose now that the retailer that carries the high quality product charges a price $\bar{p} = \bar{w}$. Then, a best response for the retailer carrying the low quality product is charging a price $\underline{p} = \underline{w}$ because any price above \bar{w} would yield no demand from either the low or high end segment. Then, the retail price equilibrium is ($\underline{p} = \underline{w}$, $\bar{p} = \bar{w}$) and the manufacturer is able to get the coordinated channel outcome.

This shows that even if a manufacturer cannot have its product line fully carried by competing retailers, it may be able to alleviate the product line distortion by having competing retailers targeting different consumer segments, if this distribution strategy is possible. However, this paradigm of perfect competition between retailers does not seem to fit reality well when competing retailers can provide service to the customers and are always able to find a variable to differentiate themselves.

Imperfect Competition Between Retailers

Let us consider now the general case in which the retailers have some market power. We will confirm that there is a continuum between perfect competition, no distortion, and monopoly, the distortion obtained in the previous section.

Consider two competing retailers. Normalize the market size to one unit and suppose α consumers are completely loyal to one retailer, α consumers are completely loyal to another retailer, and $1 - 2\alpha$ consumers are completely indifferent between the two retailers,

¹²It is also well known that perfect competition among retailers will not solve both the "service externalities" and "input substitution" effects.

with $0 \leq \alpha \leq \frac{1}{2}$.¹³ A consumer of type θ loyal to a certain retailer will buy only from that retailer and if and only if the price of the product of quality q being bought is lower than $V(\theta, q)$. A consumer of type θ indifferent between the two retailers will buy from the retailer that has the lowest price for a product of quality q being considered, and if and only if that price is lower than $V(\theta, q)$.

The parameter α is then an index of market power: Competition is more intense when α decreases. When $\alpha = 0$ we have the extreme case of perfect competition discussed above; when $\alpha = \frac{1}{2}$ we have the extreme case of local monopoly as presented in §3.

To compute the market outcome in this case, we have to first characterize the retail market equilibrium when the manufacturer offers a pair of products with qualities $\{q, \bar{q}\}$ at the manufacturer prices $\{\underline{w}, \bar{w}\}$, respectively. After computing the retail market equilibrium we can then solve for the optimal product qualities and manufacturer prices set by the manufacturer.

Consider the retail market equilibrium for given product qualities $\{q, \bar{q}\}$ and manufacturer prices $\{\underline{w}, \bar{w}\}$. Note first that for any retailer to be willing to carry the higher quality product targeted at the high end segment, it must be that its profit from selling the high quality product to a high end consumer, $\bar{p} - \bar{w}$, is greater than the profit of selling the low quality product to a high end consumer and keeping the consumer surplus constant, $\bar{p} - [V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, q)] - \underline{w}$. This reduces to $\bar{w} - \underline{w} \leq V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, q)$, which is condition (3), a condition that will always be satisfied in equilibrium because the manufacturer wants to sell the higher quality product.

Second, note that a retailer can guarantee itself both

$$\alpha\gamma[V(\underline{\theta}, q) - \underline{w}] + (1 - \gamma)$$

$$[V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, q) + V(\underline{\theta}, q) - \bar{w}]$$

by offering both products to all the loyal consumers, and $\alpha(1 - \gamma)[V(\bar{\theta}, \bar{q}) - \bar{w}]$ by targeting only the high end loyal consumers. From, §3 we already know that the former is greater than the latter if and only if

$$\underline{w} \leq \frac{V(\underline{\theta}, q) - (1 - \gamma)V(\bar{\theta}, q)}{\gamma},$$

condition (4).

¹³See, for example, Narasimhan (1988) for a similar set-up.

One can then obtain the retail market equilibrium as a function of the product qualities and the manufacturer prices (the proofs of the following two propositions are available upon request from the author).

PROPOSITION 5. Suppose condition (3) is satisfied. If

$$\underline{w} \leq \frac{V(\underline{\theta}, q) - (1 - \gamma)V(\bar{\theta}, q)}{\gamma},$$

the retail market equilibrium involves each retailer carrying always both products, and mixing on prices according to the cumulative distribution functions presented in (i)–(iii) in the appendix. If

$$\underline{w} > \frac{V(\underline{\theta}, q) - (1 - \gamma)V(\bar{\theta}, q)}{\gamma},$$

the retail market equilibrium involves each retailer carrying only the high quality product with positive probability and mixing on prices according to the cumulative distribution functions presented in (iv)–(vi) in the appendix.

This proposition shows interestingly that if condition (4) in the monopoly case is violated, the retail market equilibrium is one in which there is a positive probability of the manufacturer not selling the low quality product (see the appendix).

The following characterizes the manufacturer decisions in terms of prices and qualities being offered.

PROPOSITION 6. The manufacturer sets $\bar{w} = \underline{w} + V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, q)$. For low levels of competition (high α), the manufacturer sets

$$\underline{w} = \frac{V(\underline{\theta}, q) - (1 - \gamma)V(\bar{\theta}, q)}{\gamma},$$

(the monopoly case solution), and both consumer segments are always served with different products. For high levels of competition (low α), the manufacturer sets

$$\underline{w} > \frac{V(\underline{\theta}, q) - (1 - \gamma)V(\bar{\theta}, q)}{\gamma},$$

and while the high end consumers are always served, the low end consumers may not be served with positive probability (given the retail market equilibrium). The threshold market power $\hat{\alpha}$ is defined by (vii) in the appendix. The quality of the product targeted at the high end consumers is as in the coordinated channel case. The quality of the product targeted

at the low end consumers is lower than in the coordinated channel and is defined in conditions (viii)–(x). When the intensity of competition approaches perfect competition ($\alpha \rightarrow 0$), the market outcome approaches the one of the coordinated channel case.

This proposition shows that under competition between retailers that have some market power, we still obtain the main features of the retailer monopoly case, that the manufacturer when selling through the channel increases the length of the product line. Interestingly, one also finds that under competition, the market may result in the low quality product not being carried by either retailer with positive probability. Furthermore, when the market structure tends to perfect competition we recover the perfect competition equilibrium presented above.

Retailer with Discretion on Quality Levels

One interesting aspect that was not considered is the fact that retailers have often some discretion in changing the quality of the products they sell or the purchasing experience, for example, with cleanliness of the products, small waiting queues, availability, credit, etc. This additional retailer discretion would allow the retailers to better target the different products. Interestingly, note that Wernerfelt (1994) shows that sales assistance (which can be seen as a way for a retailer to better target the product line) is more likely to prevail when product lines are wider. It would also be expected that if the retailer has this discretion then the manufacturer may want to even widen more its product line. Chu, Gerstner, and Hess (1995), in a single product setting and competition, also model the customers' purchasing experience in addition to the product itself. Iyer (1996) considers the case where the quality decision is made only by the retailer.

Horizontal Differentiation

To focus the attention on vertical product lines, the results above also restricted their attention to vertical preferences, i.e., consumers being segmented according to their relative preference for quality. In fact, in every market consumers can also be segmented in terms of horizontal preferences—one consumer likes more "red," another consumer likes more "blue," or some consumers like more a particular manufacturer

than other consumers. The existence of horizontal preferences raises two main issues.

First, with horizontal preferences and the firms restricted to a particular positioning on the horizontal preferences, there would be a downward sloping demand of consumers with a certain intensity of preference for quality. (Some analysis of this problem is available upon request from the author.) The main result is that now, in addition to the wider product line effect, we have a "reduced demand due to higher prices" effect. The existence of an intermediary causes prices to be higher (because of margins over margins) and total demand to be lower than in the no intermediary case. In terms of the product line design and in order for the prices of the high quality product not to end up too high, the manufacturer may want to widen even more the product line. Second, with horizontal preferences, the manufacturer could, in principle, be interested in selling products horizontally differentiated, targeted at the different (horizontal) consumer segments. Without the existence of fixed costs of introducing products, this strategy of introducing a product targeted to each horizontal consumer segment would be optimal. The only constraints to this strategy would be the vertical targeting problems considered in this paper (if the consumers located at each horizontal preference have different willingness to pay for their most preferred product).

Nonlinear Pricing and Fixed Fee

It is also important to note that several well-known vertical contracts (restraints of trade) between the retailer and the manufacturer, if doable or legal, could solve the problems stated above. For example, if the manufacturer could charge the retailer a fixed fee (or any other form of nonlinear pricing), it could then recover the profit through the fixed fee and charge the retailer the marginal cost of each product per unit sold. In this way, the retailer would have the incentives to behave as in the coordinated channel. As discussed above, it may be that the manufacturer is not able to charge a fixed fee because of too much uncertainty in the market and existing significant costs of writing contracts. Empirically, fixed fees are not very frequent and when present do not seem to have the role discussed above (see, for example, Kaufman and

Lafontaine 1994 for some evidence in the context of franchising).

Tie-in Agreements

Another solution to the wider product line distortion is for the manufacturer and the retailer to contract on a tie-in agreement that would commit the retailer to buy the "correct" fixed proportion of the products in the line (full line forcing). This paper can then be seen as justifying the importance of tie-in agreements when selling a product line through a channel. However, these types of contracts may not be enforceable because of renegotiation, the impossibility of specifying ex ante the product characteristics that are ultimately valued by the the market, or monitoring costs. Moreover, the tie-in agreements (full line forcing in this case) may be considered illegal by §3 of the Clayton Act (see also Sullivan 1977, pp. 456-459).

Coupons and Other Screening by the Manufacturer

Other screening activities by the manufacturer such as coupons (Gerstner and Hess 1995), if possible, can improve the profits of the manufacturer and reduce the distortion of a longer product line. However, if these screening activities are possible with the intermediary they are also possible in the coordinated channel, and therefore, they will also reduce the distortion of the longer product line for the coordinated channel case. This means that, in comparison to the coordinated channel case, a manufacturer should still stretch its product line when an intermediary is introduced. In fact, at a conceptual level, other screening activities by the manufacturer such as coupons are nothing but changes in the design of the product line and, in that sense, are already accounted for in a formulation of the problem such as in §2 (except for the multidimensionality of characteristics).

5. Concluding Remarks

The results presented here give also some interesting managerial insights. First, from the point of view of the retailer, margins in the product line should be increasing in the product quality level. The retailer should also target different products to different consumer segments and, in particular, target products with less quality than the efficient one to the consumer

segments that value quality less. This allows the retailer to get the consumer segments that appreciate quality more to pay more for the high quality products. The manufacturer, on the other hand, should account for the retailer targeting strategy by, in comparison with the case where coordination in the channel is possible, increasing the length of the product line, targeting even lower quality products to the segments that appreciate quality less. Better coordination in the channel can be achieved through the use of tie-in agreements, which will ultimately result in reducing the length of the product line.

These results have also important implications for manufacturers that plan on starting or stopping selling their product line through an intermediary (considerations often important, for example, in the personal computer industry). For example, if a manufacturer that formerly sold direct is now planning on selling through an intermediary, it should consider seriously increasing the quality differences in the products in its line. The risks have to do with the intermediary targeting strategies being in strong disagreement with the manufacturer plans. The unit margins of both the retailer and manufacturer are also shown to be increasing with the quality level of the product. Failure for a manufacturer to account for the optimal retailer targeting strategies results in the retailer just targeting the higher end consumer segments.¹⁴

Appendix

1. Probability Distributions of Equilibrium Mixed Strategies in Proposition 5

(a)

$$w \leq \frac{V(\underline{q}, \underline{q}) - (1 - \gamma)V(\bar{q}, \underline{q})}{\gamma}$$

Denote $\underline{F}()$ and $\bar{F}()$ as, respectively, the equilibrium cumulative distribution functions for \underline{p} and \bar{p} . Then,

$$E(\underline{p}) = 1 - \frac{\alpha}{1 - 2\alpha} \frac{V(\underline{q}, \underline{q}) - \underline{p}}{\underline{p} - w}, \tag{i}$$

$$\bar{F}(\bar{p}) = 1 - \frac{\alpha}{1 - 2\alpha} \frac{V(\bar{q}, \bar{q}) - V(\bar{q}, \underline{q}) + V(\underline{q}, \underline{q}) - \bar{p}}{\bar{p} - \bar{w}} \tag{ii}$$

Furthermore, each realization of the pair (\underline{p}, \bar{p}) satisfies

¹⁴The author is grateful to Ganesh Iyer and Debu Purohit for helpful comments on an earlier version of this paper.

$$\bar{p} = g(\underline{p}) = (\underline{p} - \underline{w}) \frac{V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q})}{V(\underline{\theta}, \underline{q}) - \underline{w}}$$

$$+ \underline{w} \frac{V(\underline{\theta}, \underline{q}) - \underline{p}}{V(\underline{\theta}, \underline{q}) - \underline{w}} \quad (iii)$$

(b)

$$\underline{w} \cong \frac{V(\underline{\theta}, \underline{q}) - (1 - \gamma)V(\bar{\theta}, \underline{q})}{\gamma}$$

If

$$\bar{p} > \bar{p} \equiv \frac{V(\bar{\theta}, \bar{q})[V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q})] + \underline{w}[K_2 + V(\bar{\theta}, \underline{q}) - V(\underline{\theta}, \underline{q})]}{K_2 - \underline{w}}$$

with

$$K_2 \equiv \frac{(1 - \gamma)V(\bar{\theta}, \bar{q})[V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q}) - \underline{w}] + \gamma \underline{w}[V(\underline{\theta}, \underline{q}) - \underline{w}]}{\gamma[V(\underline{\theta}, \underline{q}) - \underline{w}] + (1 - \gamma)[V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q}) - \underline{w}]}$$

the retailer only sells the high quality product and the cumulative distribution function of \bar{p} is

$$\bar{F}(\bar{p}) = 1 - \frac{\alpha}{1 - 2\alpha} \frac{V(\bar{\theta}, \bar{q}) - \bar{p}}{\bar{p} - \underline{w}} \quad (iv)$$

If $V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q}) \leq \bar{p} \leq \bar{p}$, the cumulative distribution function of \bar{p} is a constant, i.e., there is no positive density on these \bar{p} being charged.

If $V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q}) > \bar{p}$, the cumulative distribution functions for \underline{p} and \bar{p} are, respectively,

$$F(\underline{p}) = 1 - \frac{\alpha}{1 - 2\alpha} \frac{K_1 - \underline{p}}{\underline{p} - \underline{w}} \quad (v)$$

$$\bar{F}(\bar{p}) = 1 - \frac{\alpha}{1 - 2\alpha} \frac{K_2 - \bar{p}}{\bar{p} - \underline{w}} \quad (vi)$$

where K_1 is defined by

$$K_1 \equiv \underline{w} + \frac{1 - \gamma}{\gamma} [V(\bar{\theta}, \bar{q}) - K_2]$$

Finally, each realization of the pair (\underline{p}, \bar{p}) for β in this region satisfies

$$\bar{p} = g(\underline{p}) = \frac{\underline{w}(K_1 - \underline{p}) + K_2(\underline{p} - \underline{w})}{K_1 - \underline{w}}$$

2. Threshold Market Power and Optimal q in Proposition 6(a)

Threshold market power. The threshold market power $\hat{\alpha}$ is defined by

$$1 - \frac{2\gamma^3 \alpha^2 \left[\frac{V(\underline{\theta}, \underline{q}^*) - (1 - \gamma)V(\bar{\theta}, \underline{q}^*)}{\gamma} - C(\underline{q}^*) \right]}{(1 - 2\hat{\alpha})(1 - \gamma)[V(\bar{\theta}, \underline{q}^*) - V(\underline{\theta}, \underline{q}^*)]} = 0, \quad (vii)$$

where q^* satisfies condition (10).

(b) Optimal q . The optimal q for $\alpha > \hat{\alpha}$ is

$$\underline{q} = \underline{q}^*, \quad (viii)$$

defined by condition (10). The optimal $(\underline{q}, \underline{w})$ for $\alpha \leq \hat{\alpha}$ satisfy

$$V_1(\underline{\theta}, \underline{q}) = C(\underline{q}) + \frac{1 - \gamma}{\gamma} \frac{\alpha\gamma\beta + 1 - \gamma + (1 - 2\alpha)P + \alpha\gamma}{(1 - 2\alpha)P + \alpha\gamma\beta}$$

$$[V_1(\bar{\theta}, \underline{q}) - V_1(\underline{\theta}, \underline{q})] \quad (ix)$$

and

$$\gamma(1 - P)(1 + P - 2\alpha P) - \frac{2\gamma[\underline{w} - C(\underline{q})](\alpha + P - 2\alpha P)}{V(\underline{\theta}, \underline{q}) - \underline{w}}$$

$$\left[\frac{\alpha\gamma}{1 - 2\alpha} + P \right] + 1 - \gamma = 0 \quad (x)$$

where

$$\beta \equiv (1 - P)(1 + P - 2\alpha P)$$

and

$$P \equiv \frac{\alpha}{1 - 2\alpha} \frac{(1 - \gamma)V(\bar{\theta}, \underline{q}) - V(\underline{\theta}, \underline{q}) + \gamma \underline{w}}{\gamma[V(\underline{\theta}, \underline{q}) - \underline{w}] + (1 - \gamma)[V(\bar{\theta}, \bar{q}) - V(\bar{\theta}, \underline{q}) + V(\underline{\theta}, \underline{q}) - \underline{w}]}$$

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This paper was received April 15, 1997, and has been with the author 6 months for 2 revisions; processed by Ram C. Rao.