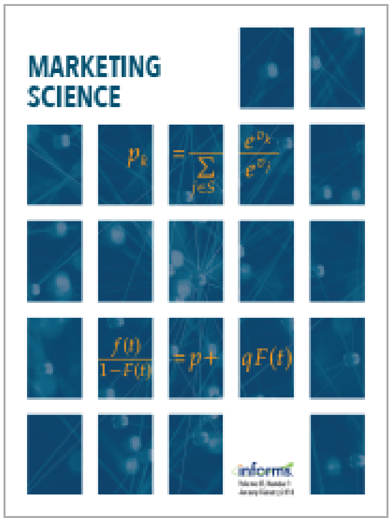

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A General Theory of Pass-Through in Channels with Category Management and Retail Competition

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I provide a general formulation of the channel pass-through problem as a comparative static of the retail price equilibrium, and I analyze the impact of category management and retail competition on pass-through, focusing on brand and retailer differences, and the nature of the cost change being passed through—whether it is brand specific, retailer specific, both, or neither.

With category management, a retailer's response to a brand-specific cost change is not limited to that brand; in general, a retailer will also change the prices of other brands. The cross-brand effect can be positive or negative, and, depending on its sign, it either enhances or attenuates pass-through. I explain the cross-brand effect as an interaction between two forces: a demand-substitution force that pushes for a negative cross-brand effect, and a strategic-complementarity force that pushes for a positive cross-brand effect. Retail competition adds another layer of strategic complementarity, causing other retailers to respond even for retailer-specific cost changes and increasing pass-through of categorywide cost changes. But its effect for brand-specific cost changes is ambiguous.

I apply the theory to two commonly used demand functions—linear demand and nested logit—and show that they have significantly different pass-through properties. The paper concludes with a discussion of how the theory relates to the empirical literature, including the companion piece by Besanko et al. (Besanko, D., J-P. Dubé, S. Gupta. 2005. Own-brand and cross-brand retail pass-through. *Marketing Sci.* **24**(1) 123–137.)

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1. Introduction

The general problem of retail pass-through is the question of how a retailer reacts to changes in its costs—in particular, to what extent it changes its prices when its costs change. In the marketing literature, this is most often interpreted as trade promotion pass-through: How much of a manufacturer's promotional price-cut a retailer passes on to consumers (see, for example, Chevalier and Curhan 1976, Walters 1989, Neslin et al. 1995, Tyagi 1999, Kumar et al. 2001). But the problem is broader than that. Pass-through issues arise not only with trade promotions, but also when a manufacturer changes its regular wholesale price—downward or upward.[1] These issues also arise independent of any manufacturer-initiated price changes. For instance, they arise when a retailer experiences an idiosyncratic cost shock (e.g., temporary change in its inventory position), or a marketwide cost shock (e.g., a change in currency exchange rates with respect to imported goods).[2]

This paper presents a general formulation of the pass-through problem as a comparative static of the retail price equilibrium. In this view, retail pass-through is a comparison between two price equilibria: one corresponding to the retailer's cost environment before the cost change, and the other corresponding to the cost environment after the cost change. The usual methodology for doing this is to model the retail price equilibrium as a function of retail costs, and examine the total derivatives of this function with respect to the various costs. I provide a general characterization

[1] For example, recently Universal Music Group cut the wholesale price of its CDs "permanently" by 25% to deal with the problem of illegal Internet file-sharing (Smith 2003, Strauss 2003). Mike Spinozzi, Borders' senior vice president and chief marketing officer, was quoted in the *Seattle Times* (Veiga 2003, p. C1) as saying: "We intend on passing the reduction to the consumer."

An example of pass-through issues created by wholesale price increases is the reaction of cable TV operators to a price increase by ESPN for its sports programming (Grant and Flint 2003).

[2] See, for example, Singer (2003) on the pass-through issues Starbucks faces in the Japanese market due to exchange-rate fluctuations. Another example of a manufacturer-independent cost change is the recent decrease in debit card fees U.S. retailers experienced due to an antitrust court settlement involving Visa and MasterCard.

of these derivatives for category-profit maximizing retailers competing with each other. The cost changes themselves are exogenous to my analysis—I study pass-through, not why costs change.[3]

The comparative-static perspective virtually forces a broader interpretation of the pass-through problem by focusing attention on the structural features of the retailer's environment—features that are relevant to a variety of pass-through situations. For instance, whether the cost change at the retailer is a trade promotion or a permanent wholesale price reduction, the retailer's response depends on the brand's elasticity of demand, the number and nature of other brands in the product category, and its competitive position vis-à-vis other retailers. The same factors play a role when passing through cost increases or cost decreases and for manufacturer-initiated or manufacturer-independent cost changes. To be sure, there are additional dynamic issues that come into play when a dynamic cost change such as a trade promotion occurs—for example, forward-buying and diversion—but their presence does not obviate the structural issues (Neslin et al. 1995, Drèze and Bell 2003). A retailer making a forward-buying and diversion decision must consider pass-through as an option, for which the structural features discussed in this paper are relevant. In addition, of course, as Drèze and Bell (2003) point out, whereas forward-buying and diversion can be eliminated by administering the trade promotion as a scan-back promotion—the retailer is given the promotional price on the units it sells, not on the units it buys—the pass-through problem does not go away and continues to be informed by the structural features of the market.

Tyagi (1999) was the first, to my knowledge, to model pass-through as a comparative static. I generalize Tyagi's formulation in several directions. First, I do not limit myself to brand-specific cost changes such as wholesale price changes. Instead, I consider the full complement of cost changes: brand- and retailer-specific cost changes (such as temporary inventory positions in a brand that are idiosyncratic to a retailer), retailer-specific (nonbrand-specific) cost changes (such as a change in labor costs localized to an online retailer), and general (nonretailer-specific, nonbrand-specific) cost changes (such as a change in credit card or debit card fees).[4] The point of recognizing this variety in cost changes is to argue that pass-through responses differ depending on the nature of the cost change being passed through (cf. Proposition 1). By not recognizing these distinctions, the existing literature does not present a complete picture of the pass-through issue, and more importantly, does not provide the right intuitions for understanding it.

Second, in contrast to much of the literature (e.g., Tyagi 1999, Kumar et al. 2001), in my model there are multiple retailers handling multiple brands. By incorporating multiple brands in the category I am recognizing the retailer's category-management concerns.[5] By incorporating multiple retailers I am recognizing the impact of retail competition. Intuitively, it seems obvious that both of these factors should be important to the pass-through issue. A retailer with several brands in a product category is concerned about category profit, not individual brands' profits. On the one hand, such a retailer might not pass on a brand-specific cost change if it diverts sales from another, more profitable brand such as a private label. On the other hand, a retailer facing competition from other retailers might be quite interested in passing on a national brand's wholesale-price cut, because not doing so would almost certainly result in loss of sales to a competitor.

I examine the impact of category management and retail competition on pass-through, focusing on brand and retailer differences and the nature of the cost change. A category-managing retailer's response to a brand-specific cost change is not limited to that brand alone; it will also change the prices of other brands in its portfolio. Similarly, a retailer competing with other retailers will find that its cost changes evoke a response from others. Traditionally, pass-through behavior has been conceptualized and studied from an individual brand or retailer's perspective. My analysis shows that this is a mistake on at least three counts. First, it misses a part of the retailer's response that affects pass-through. For instance, pass-through tends to be higher when the cross-brand effect is positive than when it is negative. Second, it misses the reaction of the other retailers, which might increase or decrease the retailer's pass-through. Third, it prevents us from seeing that a price change in a brand or retailer might not be caused by any changes to its cost at all. Rather, it might be caused by a cost change on another brand or retailer in the market. Empirical studies that do not capture cost changes in all brands in the retailer's category (such as Drèze and Bell 2003) are therefore susceptible to biased pass-through estimates. Equally, empirical studies that do not capture cost changes in competing retailers (such as Chintagunta 2002, Besanko et al. 2005) might also be susceptible to biased pass-through estimates.

[3] Other papers with exogenous cost changes include Tyagi (1999), Kumar et al. (2001), Shugan and Desiraju (2001), Besanko et al. (2005).

[4] In the sequel, when I say brand-specific cost changes without further qualification I mean brand-specific, nonretailer-specific cost changes. Similarly, *retailer-specific cost changes* means *retailer-specific nonbrand-specific cost changes*.

[5] Retailers might carry multiple product categories, but if they do, they are assumed to be independent of each other.

I show that the cross-brand effect can be positive or negative, i.e., in the same direction or in the opposite direction as the cost change. This is because with category management, there are two types of effects of a brand-specific cost change: a margin-based demand-substitution effect, which pushes for a negative price change in the other brand, and a strategic complementarity effect, which pushes for a positive price change in the other brand. In a nested-logit model (without an outside good), the two effects are roughly in balance for brand-specific cost changes, resulting in zero cross-brand effects when the brand is equally strong at both retailers, or in an equal number of positive and negative cross-brand effects when the brand is stronger at one retailer. However, for brand- and retailer-specific cost changes, the nested-logit model produces only negative cross-brand effects. In a linear-demand model without retail competition, the "equal number of positive and negative cross-brand effects" result holds for brand-specific cost changes, but with retail competition only positive cross-brand effects arise in a symmetric model. These observations explain, perhaps, why Besanko et al.'s (2005) regressions of prices on costs show both types of cross-brand effects in roughly equal number. They also explain why a retailer might want to shield its private-label brand by reducing its price in conjunction with the price of the national brand being trade-promoted (cf. Willis and O'Keeffe 1992).

By studying retailer-specific and marketwide cost changes I refine the intuition regarding the impact of retail competition on pass-through. The standard intuition is that competition enhances pass-through, but this intuition is based on single-brand retailers passing through general cost changes. For instance, in a model with no retailer differentiation, general cost changes get 100% pass-through. The impact of competition on pass-through is smaller for retailer-specific cost changes. For brand-specific cost changes, the effect of competition is further complicated by the possibility of negative cross-brand effects.

Finally, my study of two special cases, linear demand and nested logit, reveals the different ways in which the main forces manifest themselves in different demand structures. The linear-demand model is predisposed toward greater harmony among the brands within a retailer. By contrast, in the nested-logit model, the interests of competing brands are almost completely opposed within a retailer. Another major difference is that in the linear-demand model equilibrium market-share positions do not matter at all: Pass-through behavior is completely characterized by the various slopes of the demand functions. In the nested-logit model, however, equilibrium market-shares matter a great deal. Therefore, the relations between brand or retailer strength and pass-through are different in the two cases, and the conditions under which one brand or retailer produces greater pass-through than another are also different.

In §2, I present the general theory. In §3, I apply it to the two special cases of linear demand and nested-logit demand. Section 4 summarizes my results and discusses their empirical implications. All proofs not in the text are in a technical appendix available from the journal's web site.

2. The General Theory

My basic modeling framework is that of several manufacturers—brands—in a product category selling through several competing retailers on a nonexclusive basis.[6] Without loss of generality I operationalize it as two retailers, 1 and 2, each with two brands, 1 and 2, with brand 1 common to both retailers and brand 2 not necessarily so. This allows me to examine situations in which brand 1 is a national brand and brand 2 is either a retailer-specific brand such as a private label or another national brand. As a shorthand I will refer to "brand j at retailer i" as "brand ij" $(i, j = 1, 2)$.

The basic ingredient of my model is the demand function for each brand at each retailer. I shall assume that these demand functions are "nice" in the sense that they lead to "nice" profit functions that, in turn, lead to a unique pure-strategy retail equilibrium. In particular, I assume that the profit functions are twice-continuously differentiable (whenever positive) and have negative-definite Hessians (a property that implies concavity). My formulation is to be contrasted with discrete demand-function models such as Lal and Villas-Boas (1998) that have mixed-strategy equilibria only.

Let D^{ij}, $i = 1, 2$, $j = 1, 2$, denote brand j's demand function at retailer i. In general, these demand functions are functions of all four retail prices: p_{11}, p_{21}, p_{12}, p_{22}. I make no specific assumptions at this stage regarding the form of the demand functions other than to assume, naturally, that each demand function is downward sloping in its own price and upward sloping in the other prices. So, for instance, D^{21} is downward sloping in p_{21} and upward sloping in p_{11}, p_{12}, and p_{22}. The brands are in the same product category, and both retailers participate in this category, so each brand at each retailer is a partial substitute for three other products.

A basic regularity property of the demand functions ought to be that the same brand across two

[6] Even though this is easily the most common situation in retailing, it is surprisingly rare in the marketing literature, the notable exceptions being Lal and Villas-Boas (1998) and Trivedi (1998). More common are the special cases of one retailer with multiple brands (e.g., Choi 1991), multiple retailers and one brand (e.g., Iyer 1998), and multiple retailers with exclusive brands (e.g., Moorthy 1988).

retailers are closer substitutes than the same brand and a different brand across the same two retailers. In particular, $\partial D^{i1}(\tilde{p})/\partial p_{k1} > \partial D^{i1}(\tilde{p})/\partial p_{k2}$ for $i, k = 1, 2$, $k \neq i$ (where $\tilde{p} = (p_{11}, p_{12}, p_{21}, p_{22})$). Second, I require that demand for each brand at each retailer decrease (increase) when *all* prices are increased (decreased) by the same amount in coordinated fashion. That is, $\partial D^{ij}(\tilde{p})/\partial p_{ij} + \sum_{kl \neq ij} \partial D^{ij}(\tilde{p})/\partial p_{kl} < 0$ for $i = 1, 2$, $j = 1, 2$. This allows the category or market to expand or contract when all prices fall or rise. Third, I require that a price change on a given brand at a given retailer has a greater effect on demand for that brand at that retailer than all the other demand effects put together. That is, $\partial D^{ij}(\tilde{p})/\partial p_{ij} + \sum_{kl \neq ij} \partial D^{kl}(\tilde{p})/\partial p_{ij} < 0$. This simply recognizes that all the brands are in the same category and that the two retailers constitute the market.[7]

Note that I do not assume any symmetry among the brands or the retailers (unlike, say, Trivedi 1998). This allows me to investigate the impact of retailer differentiation and brand differentiation on pass-through. I summarize the demand function assumptions in Assumption 1.

Assumption 1. (*Properties of the demand function.*) *For* $i, j, k, l = 1, 2$ *and* $\tilde{p} \in \mathbb{R}^4_+$:

(a) $\dfrac{\partial D^{ij}}{\partial p_{ij}}(\tilde{p}) < 0$, $\dfrac{\partial D^{ij}}{\partial p_{kl}}(\tilde{p}) \geq 0$ *for* $kl \neq ij$,[8]

(b) $\dfrac{\partial D^{i1}}{\partial p_{k1}}(\tilde{p}) > \dfrac{\partial D^{i1}}{\partial p_{k2}}(\tilde{p})$ *for* $k \neq i$,

(c) $\dfrac{\partial D^{ij}}{\partial p_{ij}}(\tilde{p}) + \sum_{kl \neq ij} \dfrac{\partial D^{ij}}{\partial p_{kl}}(\tilde{p}) < 0$,

(d) $\dfrac{\partial D^{ij}}{\partial p_{ij}}(\tilde{p}) + \sum_{kl \neq ij} \dfrac{\partial D^{kl}}{\partial p_{ij}}(\tilde{p}) < 0$.

Retailer i's ($i = 1, 2$) category profit function is given by

$$\pi^i(\tilde{p}) = (p_{i1} - w_1 - c_{i1} - c_i - c)D^{i1}(\tilde{p}) + (p_{i2} - c_{i2} - c_i - c)D^{i2}(\tilde{p}), \tag{1}$$

where I distinguish among a variety of retailer costs that might have pass-through implications. First and foremost is the wholesale price w_1 of the national brand. This brand-specific cost is usually assumed to be common to both retailers because of Robinson-Patman Act considerations. I shall do so, as well, but note that this is an assumption, and its purpose in this paper is not just to respect the Robinson-Patman Act, but also to model correlated wholesale prices. In reality, wholesale prices often differ across retailers—in part because they incorporate volume-based discounts that vary by size of retailer (for example, see Shepard 1993 for the case of gasoline retailing) or because the manufacturer would like to encourage differentiation among retailers (Iyer 1998)—and to capture that possibility and to reflect other retailer operating costs that are brand- and retailer-specific (for example, brand- and retailer-specific inventory costs), I introduce another cost term, c_{ij}. Thus, c_{i1} and c_{i2} are retailer i's brand-specific marginal costs for brands 1 and 2, respectively. In (1) I am interpreting the second brand at each retailer as a private-label brand, whose wholesale prices are not coordinated across the retailers. I do not model a separate wholesale price for these brands; their retailer-specific wholesale prices are subsumed in c_{i2}.[9] Next, c_i is retailer i's nonbrand-specific marginal operating cost (for example, an online retailer's volume-sensitive labor cost), and finally, c refers to nonretailer-specific, nonbrand-specific marginal operating costs (for example, excise taxes). Of course, not all of these costs might apply in any given application, but by modeling all these costs we give ourselves the opportunity to discover whether different types of costs have different pass-through implications. I omit fixed costs because they do not have any implications for pass-through behavior.

As noted earlier I assume that π^i is concave in the sense that it has a negative-definite Hessian matrix. That is, for $i, j = 1, 2$, $\partial^2\pi^i(\tilde{p})/\partial p_{ij}^2 < 0$, and $(\partial^2\pi^i(\tilde{p})/\partial p_{i1}^2)(\partial^2\pi^i(\tilde{p})/\partial p_{i2}^2) - (\partial^2\pi^i(\tilde{p})/\partial p_{i1}\partial p_{i2})^2 > 0$. In addition, I shall assume that the two brands are complementary within each retailer's profit function in the sense that the marginal profit from each brand is increasing in the other brand's price. That is, $\partial^2\pi^i(\tilde{p})/\partial p_{ij}\partial p_{ik} \geq 0$ $(j \neq k)$. I call this internal strategic complementarity to distinguish it from external strategic complementarity, which, in this context, speaks to the interaction between retailers. I also assume external strategic complementarity: $\partial^2\pi^i(\tilde{p})/\partial p_{ij}\partial p_{lk} \geq 0$ $(i \neq l)$. Internal and external strategic complementarity are natural in my setting. They imply that, for any pair of demand-substitutes, if one

[7] Evidence for the within-retailer demand assumptions appears in numerous marketing studies, for example Walters (1991) and Kumar and Leone (1988). For the cross-retailer assumptions, evidence is scarcer because of the paucity of multistore studies. Kumar and Leone (1988) provide strong supportive evidence. Walters (1991), however, finds weak cross-retailer effects in general, and some of them have the wrong sign, and the wrong magnitudes—interstore substitution effects involving substitute brands stronger than interstore substitution effects involving the same brand—which he terms "somewhat puzzling" (p. 26).

[8] We allow for the possibility of zero cross-effects in order to evaluate submodels without category management or competition.

[9] When brand 2 at each retailer is a common national brand, statements about its pass-through with respect to w_2 can be derived by analogy to brand 1's pass-through with respect to w_1.

of them were to increase in price while prices outside of the pair were held constant, then whoever controls the other demand-substitute's price would find it optimal to raise it. Together, internal strategic complementarity and external strategic complementarity make each retailer's profit function supermodular when viewed as a function of $\tilde{p}$ (Sundaram 1996).[10] Finally, I assume the marginal profit analogues of Assumptions 1(b), (c), and (d):

$$\frac{\partial^2 \pi^i}{\partial p_{i1}\partial p_{k1}}(\tilde{p}) > \frac{\partial^2 \pi^i}{\partial p_{i1}\partial p_{k2}}(\tilde{p}) \quad \text{for } k \neq i,$$

$$\frac{\partial^2 \pi^i}{\partial p_{ij}^2}(\tilde{p}) + \sum_{kl\neq ij} \frac{\partial^2 \pi^i}{\partial p_{ij}\partial p_{kl}}(\tilde{p}) < 0, \quad \text{and}$$

$$\frac{\partial^2 \pi^i}{\partial p_{ij}^2}(\tilde{p}) + \sum_{kl\neq ij} \frac{\partial^2 \pi^k}{\partial p_{kl}\partial p_{ij}}(\tilde{p}) < 0.$$

Assumption 2. (*Properties of the profit function.*) *For* $i, j, l, k = 1, 2$, *and* $\tilde{p} \in \mathbb{R}_+^4$:

(a) (*Concavity.*) $\dfrac{\partial^2 \pi^i(\tilde{p})}{\partial p_{ij}^2} < 0$ *and*

$$\left(\frac{\partial^2 \pi^i(\tilde{p})}{\partial p_{i1}^2}\right)\left(\frac{\partial^2 \pi^i(\tilde{p})}{\partial p_{i2}^2}\right) - \left(\frac{\partial^2 \pi^i(\tilde{p})}{\partial p_{i1}\partial p_{i2}}\right)^2 > 0.$$

(b) (*Internal and external strategic complementarity.*) $\dfrac{\partial^2 \pi^i(\tilde{p})}{\partial p_{ij}\partial p_{lk}} \geq 0$ *for* $ij \neq lk$.[11]

(c) $\dfrac{\partial^2 \pi^i}{\partial p_{i1}\partial p_{k1}}(\tilde{p}) > \dfrac{\partial^2 \pi^i}{\partial p_{i1}\partial p_{k2}}(\tilde{p})$ *for* $k \neq i$.

(d) $\dfrac{\partial^2 \pi^i}{\partial p_{ij}^2}(\tilde{p}) + \sum_{kl\neq ij} \dfrac{\partial^2 \pi^i}{\partial p_{ij}\partial p_{kl}}(\tilde{p}) < 0.$

(e) $\dfrac{\partial^2 \pi^i}{\partial p_{ij}^2}(\tilde{p}) + \sum_{kl\neq ij} \dfrac{\partial^2 \pi^k}{\partial p_{kl}\partial p_{ij}}(\tilde{p}) < 0.$

Note that Assumptions 1 and 2 are satisfied by the linear demand function $D^{ij}(\tilde{p}) = \alpha_{ij} - \beta_{ij}p_{ij} + \gamma_{ik}p_{ik} + \delta_{lj}p_{lj} + \lambda_{lk}p_{lk}$ $(i, j, k, l = 1, 2,\ k \neq j,\ l \neq i)$, provided $\beta_{ij} > 0$; $\gamma_{ik}, \delta_{lj}, \lambda_{lk} \geq 0$; $\delta_{l1} \geq \lambda_{l2}$; $\gamma_{ik} + \delta_{lj} + \lambda_{lk}$, $\gamma_{ij} + \delta_{ij} + \lambda_{ij} < \beta_{ij}$; $-2\beta_{ij} + (\gamma_{ik} + \gamma_{ij}) + \delta_{lj} + \lambda_{lk} < 0$; and $-2\beta_{ij} + (\gamma_{ik} + \gamma_{ij}) + \delta_{ij} + \lambda_{ij} < 0$ (all of which are satisfied by, for example, $\beta_{ij} \equiv 1$, $\gamma_{ik}, \delta_{lj} \equiv 0.4$, $\lambda_{lk} \equiv 0.1$).

Henceforth, I shall revert to subscripts to indicate partial derivatives. Thus, subscript ij refers to a first-order partial derivative with respect to the retail price p_{ij}, and subscript $ijkl$ refers to a second-order partial derivative with respect to the retail prices p_{ij} and p_{kl}.

By writing each retailer's profit function as the sum of brand 1 profit and brand 2 profit, I am capturing the retailer's category-management perspective. Such a retailer takes the vector of marginal costs $(\tilde{w}_j, \tilde{c}_{ij}, \tilde{c}_i, c)$ as given and chooses two retail prices to maximize its category profit, recognizing the interdependencies among the brands in the category. Assuming interior solutions, the four first-order conditions are

$$\pi_{ij}^i(\tilde{p}) = (p_{i1} - w_1 - c_{i1} - c_i - c)D_{ij}^{i1}(\tilde{p}) + (p_{i2} - c_{i2} - c_i - c) \cdot D_{ij}^{i2}(\tilde{p}) + D^{ij}(\tilde{p}) = 0 \quad (i, j = 1, 2).$$

The solution to these first-order conditions defines the retail price equilibrium. Given Assumptions 1 and 2, a retail equilibrium exists and is unique (McKenzie 1959, Takayama 1974). What I am interested in, however, is not so much the equilibrium itself, but how the equilibrium changes when one of the marginal costs changes, i.e., the comparative statics of the retail equilibrium with respect to various costs. By symmetry, I need examine only one cost change of each type, i.e., (w_1, c_{11}, c_1, c). Totally differentiating all the first-order conditions with respect to these costs, one by one, and solving for dp_{ij}/dw_1, dp_{ij}/dc_{11}, and so on, I get the set of equations

$$-HP = C,$$

where,

$$H \equiv \begin{bmatrix} \pi_{1111}^1 & \pi_{1112}^1 & \pi_{1121}^1 & \pi_{1122}^1 \\ \pi_{1211}^1 & \pi_{1212}^1 & \pi_{1221}^1 & \pi_{1222}^1 \\ \pi_{2111}^2 & \pi_{2112}^2 & \pi_{2121}^2 & \pi_{2122}^2 \\ \pi_{2211}^2 & \pi_{2212}^2 & \pi_{2221}^2 & \pi_{2222}^2 \end{bmatrix},$$

$$P \equiv \begin{bmatrix} dp_{11}/dw_1 & dp_{11}/dc_{11} & dp_{11}/dc_1 & dp_{11}/dc \\ dp_{12}/dw_1 & dp_{12}/dc_{11} & dp_{12}/dc_1 & dp_{12}/dc \\ dp_{21}/dw_1 & dp_{21}/dc_{11} & dp_{21}/dc_1 & dp_{21}/dc \\ dp_{22}/dw_1 & dp_{22}/dc_{11} & dp_{22}/dc_1 & dp_{22}/dc \end{bmatrix},$$

$$C \equiv \begin{bmatrix} \pi_{11w_1}^1 & \pi_{11c_{11}}^1 & \pi_{11c_1}^1 & \pi_{11c}^1 \\ \pi_{12w_1}^1 & \pi_{12c_{11}}^1 & \pi_{12c_1}^1 & \pi_{12c}^1 \\ \pi_{21w_1}^2 & 0 & 0 & \pi_{21c}^2 \\ \pi_{22w_1}^2 & 0 & 0 & \pi_{22c}^2 \end{bmatrix}$$

$$= \begin{bmatrix} -D_{11}^{11} & -D_{11}^{11} & -(D_{11}^{11} + D_{11}^{12}) & -(D_{11}^{11} + D_{11}^{12}) \\ -D_{12}^{11} & -D_{12}^{11} & -(D_{12}^{12} + D_{12}^{11}) & -(D_{12}^{12} + D_{12}^{11}) \\ -D_{21}^{21} & 0 & 0 & -(D_{21}^{21} + D_{21}^{22}) \\ -D_{22}^{21} & 0 & 0 & -(D_{22}^{22} + D_{22}^{21}) \end{bmatrix}.$$

Assumptions 2(d), (e) guarantee that H has a dominant diagonal (McKenzie 1959, Takayama 1974). Therefore, we get Lemma 1.

Lemma 1 (McKenzie 1959). *$|H| > 0$, H^{-1} exists, all the elements of $-H^{-1}$ are nonnegative, and its diagonal elements are positive.*

[10] Note, however, that these profit functions when viewed as a function of $(\tilde{p}, w_1, w_2, c_{ij}, c_i, c)$ are not supermodular, as we show below.

[11] Once again, we only assume weak internal and strategic complementarity in order to evaluate submodels without category management or retail competition.

So

$$P = -H^{-1}C. \tag{2}$$

One could interpret this equation as saying that the pass-through effect of various cost changes is the net result of the interaction of two types of forces: the $-H^{-1}$ forces and the C forces. The C forces are the simple ones, representing our most basic intuition regarding cost changes—that they must be passed on where they arise, shrinking demand if there is a cost increase, expanding demand if there is a cost decrease. In a category-management context, for brand-specific cost changes, this intuition gets expanded to include the other brands whose costs have not changed: These brands' prices will be changed in the opposite direction to accelerate the desired demand-change at the focal brand by encouraging interbrand substitution. For example, $\pi^1_{11w_1} = \pi^1_{11c_{11}} = -D^{11}_{11} > 0$ is capturing the "cost changes must be passed on to shrink/expand demand" effect for brand 11, and $\pi^1_{12w_1} = \pi^1_{12c_{11}} = -D^{11}_{12} < 0$ is capturing the substitution effect via an opposite change in the price of brand 12. So if the cost of brand 1 increases, and the C forces were the only ones that mattered, one might expect the retailers to increase the price of brand 1 and decrease the price of brand 2. For categorywide cost increases, whether retailer-specific or not, there are no within-retailer substitution issues to contend with, so the C forces reduce to "cost changes must be passed on" for both brands:[12] $\pi^1_{11c_1} = \pi^1_{11c} = -(D^{11}_{11} + D^{12}_{11}) > 0$ (by Assumption 1), $\pi^1_{12c_1} = \pi^1_{12c} = -(D^{11}_{12} + D^{12}_{12}) > 0$, and $\pi^2_{21c} = -(D^{21}_{21} + D^{22}_{21}) > 0$, $\pi^2_{22c} = -(D^{21}_{22} + D^{22}_{22}) > 0$. Therefore, using Lemma 1 it is immediate that dp_{11}/dc_1, dp_{12}/dc_1, dp_{21}/dc_1, and dp_{22}/dc_1 and dp_{11}/dc, dp_{12}/dc, dp_{21}/dc, and dp_{22}/dc are all positive. The C forces specify the direction of pass-through for categorywide cost changes.

But progress in specifying the pass-through effects of brand-specific cost changes depends on coming to grips with the $-H^{-1}$ forces. These forces might be called the *strategic effects of price changes*. These effects can be internal to a retailer, arising from changes in the other brand's price at the same retailer, or external, arising from the other retailer's price changes (on the same or a different brand). It is these strategic considerations that lead to much of the complexity in the pass-through analysis of brand-specific cost changes. Even the simple assertion that own pass-throughs are positive for brand-specific cost changes is not obvious.[13] However, I am able to report progress. Lemma 2 below states that my assumptions already guarantee $[-H^{-1}]_{11} \geq [-H^{-1}]_{12}$ and $[-H^{-1}]_{33} \geq [-H^{-1}]_{34}$; hence $dp_{11}/dc_{11} > 0$ is assured. Lemma 3 identifies sufficient conditions for $[-H^{-1}]_{13} \geq [-H^{-1}]_{14}$ to assure dp_{11}/dw_1, and $[-H^{-1}]_{31} \geq [-H^{-1}]_{32}$ to assure $dp_{21}/dw_1 > 0$.

Lemma 2. *$[-H^{-1}]_{11} \geq [-H^{-1}]_{12}$; $[-H^{-1}]_{22} \geq [-H^{-1}]_{21}$; $[-H^{-1}]_{33} \geq [-H^{-1}]_{34}$; and $[-H^{-1}]_{44} \geq [-H^{-1}]_{43}$.*

Lemma 3. *If $|\pi^2_{2222}| \geq |\pi^2_{2121}|$, $\pi^1_{1221} \geq \pi^1_{1122}$ and $\pi^1_{1121} \geq \pi^1_{1222}$, then $[-H^{-1}]_{13} \geq [-H^{-1}]_{14}$. Similarly, if $|\pi^1_{1212}| \geq |\pi^1_{1111}|$, $\pi^2_{2211} \geq \pi^2_{2112}$, and $\pi^2_{2111} \geq \pi^2_{2212}$, then $[-H^{-1}]_{31} \geq [-H^{-1}]_{32}$.*[14]

Given Lemmas 2 and 3, Proposition 1 summarizes my general results.

Proposition 1.

(a) *A categorywide cost change, whether retailer-specific or general, elicits a positive price change from both retailers, for both brands. However, the price changes are greater when the cost change is general.*

(b) *A brand- and retailer-specific cost change elicits a positive pass-through on that brand, from that retailer. The other brand's retail price at that retailer, and both brands' prices at the other retailer will also change in general, but the direction of these changes is ambiguous, depending on specific magnitudes in the $-H^{-1}$ and C matrices. For example, $dp_{12}/dc_{11} > 0$ if and only if $([-H^{-1}]_{21})(-D^{11}_{11}) > ([-H^{-1}]_{22})(D^{11}_{12})$.*

(c) *A brand-specific (marketwide) cost change, such as a change in the national brand's wholesale price to both retailers, will in general elicit a price change in both brands at both retailers. Under the conditions of Lemma 3, pass-through is positive at both retailers. However, the cross-effect on the other brand's price continues to be ambiguous, depending on specific magnitudes in the $-H^{-1}$ and C matrices. For example, $dp_{12}/dw_1 > 0$ if and only if $([-H^{-1}]_{21})(-D^{11}_{11}) + ([-H^{-1}]_{23})(-D^{21}_{21}) > ([-H^{-1}]_{22}) \cdot (D^{11}_{12}) + ([-H^{-1}]_{24})(D^{21}_{22})$.*[15]

[12] Therefore, the profit functions π^i are supermodular with respect to $(\tilde{p}, c)$ and $(\tilde{p}, c_1)$, but not with respect to $(\tilde{p}, w_1)$ and $(\tilde{p}, c_{11})$.

[13] Consider, for example, $dp_{11}/dc_{11} = ([-H^{-1}]_{11})(-D^{11}_{11}) + ([-H^{-1}]_{12}) \cdot (-D^{11}_{12})$. Even though $-D^{11}_{11} > 0 \geq -D^{11}_{12}$ and $-D^{11}_{11} > D^{11}_{12}$ (by Assumption 1), there is the possibility that $[-H^{-1}]_{12} > [-H^{-1}]_{11}$. Although we assumed $|H_{11}| > H_{12}$ in Assumption 2(d), it is by no means obvious that $[-H^{-1}]_{11} \geq [-H^{-1}]_{12}$.

[14] The conditions in this lemma might be interpreted as saying that each retailer's profit function is weakly more concave in brand 2 than brand 1, so that price changes are bigger in brand 1 than brand 2 when w_1 changes marginally; and retailer 2's (retailer 1's) brand 1 has a bigger effect on retailer 1's (retailer 2's) marginal profit with respect to either brand than retailer 2's (retailer 1's) brand 2 (on the corresponding marginal profit). Effectively, we are trying to limit the effect of the intraretailer substitution effect at the other retailer (changes in p_{22} if dp_{11}/dw_1 is the focus) from overturning the "cost changes must be passed on" effect at the retailer in question. Note that if brand 2 were also a national brand and we wanted to be able to assure $dp_{12}/dw_2, dp_{22}/dw_2 > 0$, then these sufficient conditions point to symmetry between retailers and brands.

[15] For brand-specific or retailer-specific cost-changes, or both, I shall reserve the term pass-through for the price-responses of the retailer or brand whose costs changed. For instance, when a brand- and retailer-specific cost change occurs in brand 11, then dp_{11}/dc_{11} is the pass-through response (not, say, dp_{12}/dc_{11}), whereas when a retailer-

Notice that a retailer-specific categorywide cost change will elicit a response not only from the retailer affected by the cost change (the pass-through response), but also from the other retailer. This is because of the competition between the retailers. In particular, strategic complementarity implies that price changes at one retailer are transferred in kind to the other retailer. However, note that the price change is smaller in this case than when the cost change is marketwide. This is because marketwide cost changes provide two reasons for a price change, not one: the change in own costs that must be passed on, and the strategic-complementarity effect of a price change in the other retailer (cf. footnote 12). Stated differently, pass-through is greater under marketwide cost changes because competition is fiercer under marketwide cost changes; competition is fiercer under marketwide cost changes because both retailers experience the cost change (their relative competitive positions do not change).

Brand-specific cost changes, whether retailer-specific or not, elicit a response not only in the brand in question (own effects), but also in the other brand (cross-brand effects), at both retailers. As the proposition suggests, these cross-brand effects can be positive or negative. What drives these cross-brand effects? Consider the statement $dp_{12}/dc_{11} > 0$ if and only if $([-H^{-1}]_{21})(-D_{11}^{11}) > ([-H^{-1}]_{22})(D_{12}^{11})$. Suppose c_{11} increased. As noted earlier, $(-D_{11}^{11})$ and (D_{12}^{11}) capture the simple effects; these point to a negative cross-brand effect. Strategic considerations, as represented in $([-H^{-1}]_{21})$ and $([-H^{-1}]_{22})$, filter these simple effects, and push for a positive cross-brand effect. Under $\pi_{1112}^1 > 0$ (internal strategic complementarity), a price increase in brand 2 supports a price increase in brand 1. If π_{1112}^1 is relatively large vis à vis $|\pi_{1111}^1|$ (which corresponds roughly to $([-H^{-1}]_{22})/([-H^{-1}]_{21})$ being close to 1), while $(-D_{11}^{11})$ is relatively large vis à vis (D_{12}^{11}), then the strategic effect wins out, and a positive cross-brand effect results; otherwise, a negative cross-brand effect results.

The discovery of cross-brand effects is a by-product of the comparative-statics approach to pass-through. Given that much of the previous pass-through literature has not taken a comparative-statics approach, these effects do not find much mention there. However, they have been discussed in the private-label literature, under the rubric of *shielding* (Cotterill et al. 2000, Hoch et al. 2001). Shielding is the phenomenon of a retailer protecting its private-label's category share by discounting the private label in step with any discounts on the national brand (Willis and O'Keeffe 1992). In my framework, shielding is a positive cross-brand effect, and is not an inevitable consequence of category management. In fact, I will show later that in a nested-logit model without an outside good, brand-specific retailer-specific cost changes produce only negative cross-brand effects.[16]

specific cost change occurs at retailer 1, then dp_{11}/dc_1 and dp_{12}/dc_1 are both pass-through responses. Sometimes I refer to the pass-through response as an "own effect" when the meaning is clear.

2.1. Retail Competition Without Category Management

A retailer who does not practice category management views each brand in isolation, ignoring the interdependencies among the brands in the category. I capture such behavior by setting $D_{ik}^{ij} = 0$ for $k \neq j$ and, correspondingly, $\pi_{ijik}^i = 0$ and $\pi_{ijlk}^i = 0$ for $k \neq j$ and $l \neq i$. Then

$$-H^{-1} = \begin{bmatrix} -\pi_{2121}^2/A & 0 & \pi_{1121}^1/A & 0 \\ 0 & -\pi_{2222}^2/B & 0 & \pi_{1222}^1/B \\ \pi_{2111}^2/A & 0 & -\pi_{1111}^1/A & 0 \\ 0 & \pi_{2212}^2/B & 0 & -\pi_{1212}^1/B \end{bmatrix}$$

$$\text{and} \quad C = \begin{bmatrix} -D_{11}^{11} & -D_{11}^{11} & -D_{11}^{11} & -D_{11}^{11} \\ 0 & 0 & -D_{12}^{12} & -D_{12}^{12} \\ -D_{21}^{21} & 0 & 0 & -D_{21}^{21} \\ 0 & 0 & 0 & -D_{22}^{22} \end{bmatrix},$$

where $A = (\pi_{1111}^1)(\pi_{2121}^2) - (\pi_{1121}^1)(\pi_{2111}^2) > 0$ and $B = (\pi_{1212}^1)(\pi_{2222}^2) - (\pi_{1222}^1)(\pi_{2212}^2) > 0$. The following proposition is then immediate.

Proposition 2. *Without category management*:

(a) *Brand-specific cost changes, whether retailer specific or not, elicit positive pass-through effects but no cross-brand effects.*

(b) *A brand- and retailer-specific cost change has the same positive pass-through effect as an equivalent categorywide retailer-specific cost change.*

(c) *A retailer-specific cost change elicits a larger price-change at that retailer than at the other retailer.*

(d) *Marketwide cost changes elicit greater pass-through than equivalent retailer-specific cost changes.*

Part (d) of the proposition is probably the most interesting: It extends the second part of Proposition 1(a)

[16] Anecdotal evidence for a real-world negative cross-brand effect is provided in the following quotation from David Nickila of Portland French Bakery, a small bakery supplying grocery stores in Portland, Oregon: "Now, they've taken that—one day they all of a sudden up-price all your products, and then right next to you they're running 99 cents on all the major player's products" (http://www.ftc.gov/bc/slotting/slotting (1.pdf, p. 179).

to brand-specific cost changes. Marketwide cost changes generate greater pass-through than retailer-specific cost changes because, as noted earlier, the retailers compete harder when their competitive positions are equally affected by cost changes.

What is the effect of retail competition on pass-through? Suppose there was no retail competition in this case. Then $-H^{-1}$ would further simplify to

$$\begin{bmatrix} -\pi^2_{2121}/A' & 0 & 0 & 0 \\ 0 & -\pi^2_{2222}/B' & 0 & 0 \\ 0 & 0 & -\pi^1_{1111}/A' & 0 \\ 0 & 0 & 0 & -\pi^1_{1212}/B' \end{bmatrix},$$

where $A' = (\pi^1_{1111})(\pi^2_{2121}) > A$ and $B' = (\pi^1_{1212})(\pi^2_{2222}) > B$. Simple computations then reveal Proposition 3.

Proposition 3. *Without category management, the presence of retail competition boosts pass-through for every type of cost change.*

2.2. Category Management Without Retail Competition

This is the model assumed in much of the empirical literature (e.g., Sudhir 2001) and in some of the theoretical literature (e.g., Shugan and Desiraju 2001). Without retail competition,

$$-H^{-1} = \begin{bmatrix} -\pi^1_{1212}/X & \pi^1_{1112}/X & 0 & 0 \\ \pi^1_{1211}/X & -\pi^1_{1111}/X & 0 & 0 \\ 0 & 0 & -\pi^2_{2222}/Y & \pi^2_{2122}/Y \\ 0 & 0 & \pi^2_{2221}/Y & -\pi^2_{2121}/Y \end{bmatrix}$$

and

$$C = \begin{bmatrix} -D^{11}_{11} & -D^{11}_{11} & -(D^{11}_{11}+D^{12}_{11}) & -(D^{11}_{11}+D^{12}_{11}) \\ -D^{11}_{12} & -D^{11}_{12} & -(D^{12}_{12}+D^{11}_{12}) & -(D^{12}_{12}+D^{11}_{12}) \\ -D^{21}_{21} & 0 & 0 & -(D^{21}_{21}+D^{22}_{21}) \\ -D^{21}_{22} & 0 & 0 & -(D^{22}_{22}+D^{21}_{22}) \end{bmatrix},$$

where $X = (\pi^1_{1111})(\pi^1_{1212}) - (\pi^1_{1112})^2 > 0$ and $Y = (\pi^2_{2121}) \cdot (\pi^2_{2222}) - (\pi^2_{2122})^2 > 0$.

Proposition 4. *Without retail competition*:

(a) *Retailer-specific cost changes, whether brand specific or not, do not elicit cross-retailer price responses.*

(b) *A retailer-specific cost change has the same pass-through effect on the retailer's two brands as an equivalent general cost change.*

(c) *A retailer- and brand-specific cost change evokes the same price response in the retailer's two brands as an equivalent brand-specific cost change.*

(d) *A brand-specific cost change has a positive pass-through effect at both retailers. The cross-brand effect of brand* 1 *at retailer* 1 (*retailer* 2) *is positive if and only if* $(|\pi^1_{1111}|)(D^{11}_{12}) < (\pi^1_{1211})(|D^{11}_{11}|)$ (*respectively,* $(|\pi^2_{2121}|)(D^{21}_{22}) < (\pi^2_{2221})(|D^{21}_{21}|)$). *If the cross-brand effect is positive, then its magnitude is always smaller than the own effect. If the cross-brand effect of brand* 1 *at retailer* 1 (*retailer* 2) *is negative, then its magnitude is smaller than the own effect if* $|\pi^1_{1212}| \geq |\pi^1_{1111}|$ (*respectively,* $|\pi^2_{2222}| \geq |\pi^2_{2121}|$).

Part (a) of the proposition documents the obvious effect of no retail competition. Part (b) changes the second part of Proposition 1(a). In the absence of retail competition, general cost changes do not elicit greater pass-through than retailer-specific cost changes. The first part of 4(d) says that, in the absence of retail competition, a positive pass-through of brand-specific cost changes is guaranteed: No longer do we need the conditions of Lemma 3. Part (c), in conjunction with part (d), removes the ambiguity in Proposition 1(b) with respect to the cross-brand effect of brand-specific cost changes. In the simpler setting of no retail competition, $[-H^{-1}]_{21}$ and $[-H^{-1}]_{22}$ have a direct interpretation in terms of π^1_{1211} and $|\pi^1_{1111}|$, respectively. Now I can state that a change in brand 1's cost will have a positive effect on brand 2's retail price if and only if $(|\pi^1_{1111}|)(D^{11}_{12}) < (\pi^1_{1211})(|D^{11}_{11}|)$. This condition generalizes the condition in Shugan and Desiraju (2001) for the linear-demand case. In Shugan and Desiraju there is a cross-brand effect only if the two brands are asymmetrically differentiated. My condition shows that even symmetrically differentiated brands could elicit cross-effects in response to brand-specific cost changes.

How does retail competition interact with category management? In general, the effect of competition is to boost strategic complementarity in the system, but this means that both positive and negative price changes are transmitted in kind to the other retailer, reinforcing those changes. This will increase pass-through for general and retailer-specific cost changes because cross-brand effects are positive in these cases, but for brand-specific cost changes, where the possibility of negative cross-brand effects arises, the net effect is ambiguous.

3. Two Examples

In this section, I illustrate Propositions 1–4 by examining two popular demand functions: linear demand and nested-logit demand.

Linear Demand

Let $D^{ij}(\tilde{p}) = \alpha_{ij} - \beta_{ij}p_{ij} + \gamma_{ik}p_{ik} + \delta_{lj}p_{lj} + \lambda_{lk}p_{lk}$ $(i, j, k, l = 1, 2,\ k \neq j,\ l \neq i)$. As noted earlier, in order to satisfy Assumptions 1 and 2, I need $\beta_{ij} > 0$, $\gamma_{ik}, \delta_{lj}, \lambda_{lk} \geq 0$, $\delta_{l1} \geq \lambda_{l2}$, $\gamma_{ik} + \delta_{lj} + \lambda_{lk}, \gamma_{ij} + \delta_{ij} + \lambda_{ij} < \beta_{ij}$, $-2\beta_{ij} + (\gamma_{ik} + \gamma_{ij}) + \delta_{lj} + \lambda_{lk} < 0$, and $-2\beta_{ij} + (\gamma_{ik} + \gamma_{ij}) + \delta_{ij} + \lambda_{ij} < 0$. Trivedi (1998) and Shugan and Desiraju (2001) examine special cases of this demand function.

Now

$$H = \begin{bmatrix} -2\beta_{11} & \gamma_{11}+\gamma_{12} & \delta_{21} & \lambda_{22} \\ \gamma_{11}+\gamma_{12} & -2\beta_{12} & \lambda_{21} & \delta_{22} \\ \delta_{11} & \lambda_{12} & -2\beta_{21} & \gamma_{21}+\gamma_{22} \\ \lambda_{11} & \delta_{12} & \gamma_{21}+\gamma_{22} & -2\beta_{22} \end{bmatrix} \quad \text{and}$$

$$C = \begin{bmatrix} \beta_{11} & \beta_{11} & \beta_{11}-\gamma_{11} & \beta_{11}-\gamma_{11} \\ -\gamma_{12} & -\gamma_{12} & \beta_{12}-\gamma_{12} & \beta_{12}-\gamma_{12} \\ \beta_{21} & 0 & 0 & \beta_{21}-\gamma_{21} \\ -\gamma_{22} & 0 & 0 & \beta_{22}-\gamma_{22} \end{bmatrix}.$$

It is easy to establish that:

1. Pass-through of any kind is independent of cost differences and demand-intercept differences among retailers or brands. Therefore, empirical models that rely on demand intercepts to capture brand or retailer fixed effects are structurally incapable of finding pass-through differences among brands or retailers. Slope differences are necessary.

2. Without category management:

• For retailer-specific cost changes each retailer has the same pass-through rate, even when the retailers are asymmetric. However, the cross-retailer price changes, although positive, are not symmetric in general: $dp_{21}/dc_{11} = dp_{21}/dc_1 > dp_{11}/dc_{21} = dp_{11}/dc_2$ if and only if $\beta_{11}\delta_{11} > \beta_{21}\delta_{21}$; $dp_{22}/dc_1 > dp_{12}/dc_2$ if and only if $\beta_{12}\delta_{12} > \beta_{22}\delta_{22}$.

• Brand-specific cost changes generate asymmetric pass-throughs at the two retailers: $dp_{11}/dw_1 = dp_{11}/dc > dp_{21}/dw_1 = dp_{21}/dc$ if and only if $\beta_{21}\delta_{21} > \beta_{11}\delta_{11}$; $dp_{12}/dc > dp_{22}/dc$ if and only if $\beta_{22}\delta_{22} > \beta_{12}\delta_{12}$.

• Brand-specific cost changes generate more pass-through than retailer-specific cost changes because, as noted before, the strategic-complementarity effect of competition is bigger when both retailers experience the cost change.

3. Without retail competition:

• Brand-specific cost changes generate less than 100% own pass-through. Comparing brands (assuming brand 2 is national for the w-change comparison), $dp_{11}/dw_1 = dp_{11}/dc_{11} > dp_{12}/dw_2 = dp_{12}/dc_{12}$ if and only if $\gamma_{11} > \gamma_{12}$.

• Brand-specific cost changes have a cross-brand effect if and only if the brands are asymmetric on the γ-dimension: $dp_{12}/dw_1 = dp_{12}/dc_{11} \propto [(\gamma_{11} - \gamma_{12})\beta_{11}]$; $dp_{11}/dw_2 = dp_{11}/dc_{12} \propto [(\gamma_{12} - \gamma_{11})\beta_{12}]$.[17] In other words, the final arbiter of whether the strategic-complementarity forces or the C forces win out depends on the nature of cross-demand asymmetries. If brand 1 has a bigger effect on brand 2's demand than vice versa ($\gamma_{11} > \gamma_{12}$), then its cross-brand effect will be positive. Furthermore, if one brand has a positive cross-brand effect then the other must have a negative cross-brand effect. This explains perhaps why Besanko et al. (2005) find approximately 50% of their significant cross-brand effects positive.

• Positive cross-brand effects support greater pass-through for brand-specific cost changes. For instance, for a given γ_{11}, a positive dp_{12}/dc_{11} implies $dp_{11}/dc_{11} > (2\beta_{12}\beta_{11} - (\gamma_{11} + \gamma_{12})\gamma_{11})/X$ whereas a negative dp_{12}/dc_{11} implies $dp_{11}/dc_{11} < (2\beta_{12}\beta_{11} - (\gamma_{11}+\gamma_{12})\gamma_{11})/X$ (where X is positive).

4. In the symmetric linear model, cross-brand effects are positive under retail competition. This is to be contrasted with the no-retail-competition case above where asymmetry between brands was necessary for a nonzero cross-brand effect. The difference tells a story about the role of retail competition. Retail competition boosts the strategic complementarity between brands leading to a positive cross-brand effect when the internal battle between the strategic forces and the C forces is a dead heat.

5. From the foregoing observations, it is difficult to define a simple measure of brand or retailer strength that can order brands or retailers in terms of their pass-through. Brand or retailer strength, insofar as pass-through is concerned, is a multidimensional object in the linear model.

Nested Logit

Logit demand structures are common in empirical work in marketing, perhaps second only to linear-demand functions in popularity, but they are usually single-stage models with brand choice only (e.g., Sudhir 2001). Because retail competition is a crucial part of my analysis, and the linear model has already dealt with it in a single-stage manner, I examine a nested-logit model here, with retailer choice forming the first stage, and brand choice forming the second stage. That is, $D_{ij} = NS_iS_{ij}$ for $i, j = 1, 2$, where N is the size of the market, S_{ij} is brand j's share within retailer i, and S_i is retailer i's share. In the nested-logit specification,

$$S_{ij} = \frac{\exp(\alpha_{ij} - p_{ij})/\mu_b}{\sum_{k=1}^{2}\exp(\alpha_{ik} - p_{ik})/\mu_b}, \tag{3}$$

$$S_i = \frac{\exp(R_i/\mu_r)}{\sum_{k=1}^{2}\exp(R_k/\mu_r)}, \tag{4}$$

where $R_i = \mu_b \ln[\sum_{k=1}^{2}\exp(\alpha_{ik} - p_{ik})/\mu_b]$ for $i = 1, 2$, $\mu_r \geq \mu_b$ are the heterogeneity parameters for retailer choice and brand choice, respectively, and the α_{ij} are parameters reflecting the quality of the retailer-brand combination ij. In practice, one would split up α_{ij} into $r_i + b_j$, with r_i referring to the quality of retailer i, e.g., service quality, and b_j brand j's quality. Note that

[17] This point is also made in Shugan and Desiraju (2001).

we are making the "no outside good" assumption. In this context, the no-retail competition case does not make sense: Category management implies infinitely high prices on both brands then. The analysis can be extended to incorporate an outside good along the lines of footnote 19.

For the nested-logit demand structure, instead of computing H^{-1}, it turns out to be easier to exploit a special property of this structure, namely that at each retailer category profit maximization implies equal margins for both brands (Anderson et al. 1992, p. 251).[18] That is,

$$p_{ij} - (w_j + c_{i1} + c_i + c) = \frac{\mu_r}{1 - S_i} \quad \text{for } i, j = 1, 2. \tag{5}$$

Totally differentiating these equations with respect to w_1, c_{11}, c_1, and c, I get

$$P = \begin{bmatrix} 1 + \frac{1}{|\Delta|}\left(\frac{S_1}{1-S_1}\right)^2 (S_{21} - S_{11}) & 1 - \frac{1}{|\Delta|}\left(\frac{S_1}{1-S_1}\right)^2 S_{11} & \frac{1}{|\Delta|}\frac{1}{1-S_1} & 1 \\ \frac{1}{|\Delta|}\left(\frac{S_1}{1-S_1}\right)^2 (S_{21} - S_{11}) & -\frac{1}{|\Delta|}\left(\frac{S_1}{1-S_1}\right)^2 S_{11} & \frac{1}{|\Delta|}\frac{1}{1-S_1} & 1 \\ 1 - \frac{1}{|\Delta|}(S_{21} - S_{11}) & \frac{1}{|\Delta|} S_{11} & \frac{1}{|\Delta|} & 1 \\ -\frac{1}{|\Delta|}(S_{21} - S_{11}) & \frac{1}{|\Delta|} S_{11} & \frac{1}{|\Delta|} & 1 \end{bmatrix}, \tag{6}$$

where $|\Delta| = 1 + (S_1/1 - S_1) + (S_1/1 - S_1)^2 > 1$. Note that $1/(|\Delta|(1 - S_1)) = (1 - S_1)/(1 - S_1(1 - S_1)) < 1$ and $S_1^2/(|\Delta|(1 - S_1)^2) = S_1^2/(S_1^2 + 1 - S_1) < 1$. From this, we can establish:

1. General cost changes generate 100% pass-through in both brands at both retailers.

2. Retailer-specific cost changes generate equal, positive, less than 100% pass-through in both brands of the retailer, and a smaller, positive, equal pass-through in both brands of the other retailer.

   • The pass-through is greater for the retailer with the bigger equilibrium marketshare.

3. Retailer- and brand-specific cost changes generate positive, less than 100%, own pass-through, but negative cross-brand effects. This shows that the nested-logit model without an outside good is naturally predisposed toward negative cross-brand effects. It is possible for the cross-brand effect to be greater in magnitude than the pass-through if the equilibrium within-retailer share of the brand is large. Both brands of the other retailer see equal, positive, price changes.

   • Comparing brands within a retailer (i.e., comparing dp_{11}/dc_{11} and dp_{12}/dc_{12}), pass-through is greater for the brand that has a lower within-retailer equilibrium market share at that retailer.[19]

   • Comparing retailers for a given brand, say brand 1 (i.e., comparing dp_{11}/dc_{11} and dp_{21}/dc_{21}), own pass-through is greater at retailer 1 than at retailer 2 if and only if $[S_1/(1 - S_1)]^2 S_{11} < [S_2/(1 - S_2)]^2 S_{21}$.

4. Marketwide brand-specific cost changes generate positive pass-through at both retailers, greater than the pass-through with retailer- and brand-specific cost changes. The pass-through is 100% at both retailers if the brand has equal market share at both retailers; otherwise, it may be greater or less than 100% depending on whether the brand has a smaller or larger market share at the retailer where the pass-through is examined. The cross-brand effect is positive whenever the pass-through is greater than 100%; otherwise, it is negative or zero.

   • Comparing brands within a retailer (i.e., comparing dp_{11}/dw_1 and dp_{12}/dw_2), which brand gets greater pass-through depends not so much on its strength vis à vis the other brand, but rather on its strength at the subject retailer vis à vis its strength at the other retailer. For example, it is possible that brand 1 is stronger than brand 2 at both retailers (say, market shares of 0.7 and 0.3, respectively, at retailer 1, and market shares of 0.6 and 0.4 at retailer 2), but because brand 1 does relatively poorly at retailer 2 it gets less pass-through at retailer 1 than does brand 2. Note that brand 1 is weaker at retailer 1 versus retailer 2 if and only if brand 2 is stronger at retailer 1 versus retailer 2.

   • Comparing retailers for a given brand, pass-through is greater at the retailer where the brand has a smaller within-retailer market share.

5. Unlike the linear model, equilibrium market-share positions matter for pass-through. Market shares are higher for the brand or retailer with lower cost or higher quality. This means that inherited advantages and disadvantages—advantages and disadvantages independent of the cost change in question, for example, due to other costs—play a role in pass-through in the nested-logit model.

The possibility of positive cross-brand effects under marketwide brand-specific cost changes, when only negative cross-brand effects obtain for retailer- and brand-specific cost changes, shows once again the strategic-complementarity-increasing effect of retail competition. Competition's effect is weaker under retailer-specific cost changes, and the nested-logit

[18] With an outside good at each retailer, the equal-margins result still holds, but the expressions for the equilibrium margins are different from below, namely $m_i = 1/[(1 - S_i)(1 - S_{i0})/\mu_r + S_{i0}/\mu_b]$ for $i = 1, 2$, where S_{i0} is the outside good's equilibrium share at retailer i.

[19] This result, and earlier ones, on the effect of retailer- and brand-specific cost-changes, are consistent with Sudhir's (2001) results obtained in a single-stage logit model with outside good and no retail competition.

model has naturally strong demand-substitution forces. So the latter prevail under retailer- and brand-specific cost changes. Under marketwide brand-specific cost changes, however, competition's strategic-complementarity effect is stronger, so the cross-brand effect ends up being both positive and negative. In the linear model, where the demand-substitution forces are naturally weaker, positive cross-brand effects are seen even without competition for retailer-specific cost changes.

4. Conclusion

This paper presents a comparative-statics analysis of equilibrium pass-through in channels where retailers manage product categories with several brands and face competition from other retailers. The focus of the analysis is on how different types of cost changes are passed through, and how retail competition, category management, and brand and retailer differences affect pass-through.

A virtue of the comparative-statics approach is that it demonstrates the systemwide effects of a cost change. Because of category management, a retailer's response to a brand-specific cost change is not limited to the brand whose costs changed; other brands will be affected as well. Whether this cross-brand effect is in the same direction as the cost change (a positive price change) or in the opposite direction (a negative price change) depends on how two forces play out. A demand-substitution force argues for demand to be substituted away from (toward) the brand whose costs have increased (decreased), hence a negative price change, but a strategic-complementarity force argues that a positive price change in other brands will support passing through the cost change. Retail competition adds a layer of strategic complementarity to this picture, transmitting the positive and negative forces in kind to the other retailer, strengthening both and leaving the net cross-brand effect ambiguous in general. Besanko et al. (2005) find evidence of both positive and negative cross-brand effects, roughly equal in number, which is consistent with this paper.

The theory laid out in this paper sheds light on the practice of shielding private-label brands when national brands are promoted in response to a trade promotion. In my framework, this is nothing but a positive cross-brand effect, resulting from a strategic-complementarity effect overcoming a demand-substitution effect. But, as I have argued, it could go the other way—the cross-brand effect can be negative. Casual discussions of the phenomenon, however, paint a picture of a retailer always looking for opportunities to favor or protect the private-label brand, the argument being that margins are higher on the private label. But margins are not exogenous objects; they arise endogenously in price equilibrium. Any basis for favoring a private-label brand is already reflected in equilibrium prices. When costs change on the national brand, we move to a new retail equilibrium, and in this movement it is not clear that private labels need further protection.

The possibility of cross effects means that it is a mistake to automatically categorize any price changes in a brand or retailer as a pass-through response. In fact, these changes might have a causal basis in other brands or retailers, and not recognizing these external roots in empirical analyses might lead to biased pass-through estimates. For instance, Drèze and Bell (2003) regress a given retailer's prices against corresponding trade promotions only (among other variables). If trade promotions of other brands or retailers are correlated with the ones in the study, then their pass-through coefficients could be biased. Chintagunta (2002) and Besanko et al. (2005) account for the wholesale prices of all brands at a retailer, avoiding one potential source of bias, but they do not consider retail competition. So their pass-through and cross-brand effect estimates could be biased if wholesale price changes at their retailers are correlated with wholesale price changes at competing retailers.

This paper focuses on retail price changes motivated by cost changes, but there is a literature in marketing and economics of retail price changes motivated by price discrimination (Conlisk et al. 1984, Banks and Moorthy 1999) and competitive considerations (Varian 1980, Narasimhan 1988). Whereas it is not a question of which of these models is the "right" one—real-world retailing probably features all of these models to some extent, and nothing prevents more than one model from applying at the same time (for example, Sobel 1984 combines price discrimination and competition)—it is nevertheless useful to ask, in specific retailing contexts, whether retail price changes are occurring more for one reason than another. On the one hand, if price changes are motivated by cost changes, especially common cost changes, then they should be positively correlated across retailers. On the other hand, price changes motivated by price discrimination or competitive considerations are more likely to be uncorrelated across retailers.

What do the data show? Not much data are available, and the data that are available are somewhat contradictory. Walters (1991), working with grocery-store scanner data on spaghetti and spaghetti sauce, reports correlations ranging from −0.35 to 0.57 for the same brand across stores and correlations in the range −0.38 to 0.59 for different brands across stores. Villas-Boas (1995) finds, in grocery-scanner data on coffee and saltine crackers, that the same-brand correlation is, on average, 0.74, whereas for different brands it is 0.52. Rao et al. (1995) do not examine price correlation directly, but rather the concurrence of unadvertised specials on the same brand of ketchup across stores. They find that the concurrence varies by brand and the nature of the stores involved (whether high-low (Hi-Lo) or everyday-low-price (EDLP)). For example, for the two Hi-Lo stores in their sample, the two leading brands, Heinz and Hunt's, have concurrent unadvertised specials 18.1% and 37.7% of the time, respectively. Pesendorfer (2002) also finds that price changes in Hunt's are more correlated across stores (0.21) than price changes in Heinz (0.04).

It should be noted, however, that strictly coincident price changes across stores—say, in the same week—might be too strong a test of cost changes being passed through. As I noted earlier, even cost changes specific to a retailer trigger a response from other retailers in equilibrium, but this response arises as a reaction to the price change by the retailer whose costs changed—the cost change itself being unobserved by the other retailers. In reality, such a response is unlikely to be simultaneous, even in a simultaneous-move game. More likely, the reaction occurs after the focal retailer has adjusted its price. By contrast, a trade promotion common to all retailers might trigger a more simultaneous response from all retailers, although still not exactly simultaneous. This is because each retailer might independently delay its response to the promotion for idiosyncratic reasons such as inventory positions. In short, pass-through of cost changes might not necessarily show up as simultaneous price changes at competing stores.

In addition, of course, competition between retailers takes different forms. In grocery retailing—the type of retailing most studied in the marketing literature—competition between stores is unlikely to be revealed in individual product categories. Each category is low priced, and consumers typically buy many groceries on each visit. Their unit of comparison, if there is one, is likely to be shopping baskets rather than individual categories, much less individual brands. The decision on where to shop becomes a strategic long-term decision, not a tactical week-to-week decision.[20] Store loyalty over long periods is inevitable (Pesendorfer 2002). Under these circumstances it might be the overall positioning of the store that matters—by which I mean the strategic choices the store makes with respect to things such as quality of meat or produce, assortment, availability of parking, price level, and so on—rather than individual brands' weekly prices. For high-ticket goods bought less frequently, however, where the phenomenon of focussed shopping exists, competition is likely to be more tactical, and competitiveness in individual categories, and in focal brands, are both likely to be more important. In these product categories price changes across retailers, particularly in response to common external events, are more likely to be correlated (Warner and Barsky 1995).

[20] There is, of course, an extremely price-sensitive group of consumers that shops individual grocery categories every week, but by all accounts this cherry-picking segment is a small group. Exceptions also must be made for shoppers whose needs in particular categories are large enough to make them want to switch grocery stores on a week-to-week basis. For families with infants, for example, disposable diapers might be such a category. Kumar and Leone (1988) find cross-store demand effects several orders of magnitude larger in the disposable-diaper category than those found in smaller-ticket grocery-store categories, such as spaghetti or cake mix (Walters 1991), or tuna (van Heerde et al. 2004).

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