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TESTING THE THEORY: VERTICAL STRATEGIC INTERACTION AND DEMAND FUNCTIONAL FORM

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Testing the Theory:
Vertical Strategic Interaction and Demand Functional Form

Abstract

Formulating theoretical models inevitably requires various simplifications that assist in making analysis tractable and that facilitate deriving closed form solutions. While the strategic insights gained from theoretical models of market phenomena are often quite valuable, testing the theoretical assumptions made in these models can aid in assessing the broader applicability of the conclusions drawn. This is particularly true in the channels area, where the focus of research to date has largely been theoretical in nature.

In an initial attempt to examine some of the assumptions made in previous theoretical research (*e.g.*, Jeuland and Shugan 1983, McGuire and Staelin 1983, Choi 1991, Raju, Sethuraman and Dhar 1995), we focus on a limited set of issues. First, we empirically examine the vertical channel assumptions made in two well-cited models of retailer-manufacturer interaction: a) the Choi (1991) Manufacturer-Stackelberg (MS) model, and b) the Raju, Sethuraman and Dhar (1995) Stackelberg model addressing store brands. Specifically, empirical tests are developed for Manufacturer Stackelberg conduct and the use of proportional mark-up rules within the channel. Second, since each of these models assume relatively simple linear demand structures, we examine how well linear demands characterize actual market behavior by comparing them to a flexible non-linear form, the LA/AIDS model.

The empirical analysis is conducted using data for six individual categories (milk, butter, bread, pasta, margarine and instant coffee) across 59 local markets in 1991 and 1992. The empirical results generally support the assumptions of proportional mark-up behavior by retailers and Manufacturer Stackelberg conduct within the channel. While this lends support to the assumptions made in a number of theoretical models addressing channel behavior, we reject linear demands in a favor of a more flexible non-linear form. When combined with the analytical work of Lee and Staelin (1997), this suggests that additional theoretical and empirical work is needed in order to fully understand the implications of using a linear demand specification.

Keywords: Pricing; Channels; Private Labels; Competitive Strategy

1. Introduction.

Formulating theoretical models inevitably requires various simplifications that assist in making analysis tractable and that facilitate deriving closed form solutions. While the strategic insights gained from theoretical models of market phenomena are often quite valuable, understanding and assessing the theoretical underpinnings of these models can aid in assessing the broader applicability of the conclusions drawn. More specifically, empirical analysis can i) assist in providing perspective on how realistic the assumptions made in the theoretical analysis are, ii) guide theoretical researchers to critically examine the robustness of the conclusions drawn from assumptions that may only partially reflect actual market behavior, and iii) provide guidance for future theoretical research.

This is particularly true in the channels area, where the focus of research to date has largely been theoretical in nature. For example, while previous work (*e.g.*, McGuire and Staelin 1983, Jeuland and Shugan 1983, Choi 1991, Raju, Sethuraman and Dhar 1995) has generally assumed a linear demand structure, Moorthy and Fader (1990) noted that in a bilateral monopoly, the form of the demand function is directly associated with type of strategic interaction within the channel. Building on this, recent theoretical work (Lee and Staelin 1997) has shown that "the type of vertical strategic interaction present in a given environment is closely related with the convexity of the demand curve and the level of demand for a given price" (p. 185). They demonstrate that a demand structure of the type used in Raju, Sethuraman and Dhar (1995) and Choi (1991) leads to positive within-channel reactions, whereas non-linear demand structure can lead to positive, negative or no reaction within the channel. Further, as demonstrated elsewhere (Cotterill, Putsis and Dhar 1999), Genesove and Mullin 1998), assuming linear demands implies a fixed and constant pass-through rate within the channel, which imposes a fairly restrictive constraint on vertical behavior.

In an initial attempt to examine some of the assumptions inherent in previous theoretical research (*e.g.*, Jeuland and Shugan 1983, McGuire and Staelin 1983, Choi 1991, Raju, Sethuraman and Dhar 1995), we focus on a limited set of issues. First, we empirically examine the channel assumptions made in two well-cited models of retailer-manufacturer interaction: a) the Choi (1991) Manufacturer Stackelberg (MS) model, and b) the Raju, Sethuraman and Dhar (1995) Stackelberg model of store brand introduction. We focus on the Choi (1991) paper in part because it forms the basis for much of the analysis in subsequent research, including Lee and Staelin (1997). We focus on the Raju, Sethuraman and Dhar (1995) framework since it directly addresses issues pertaining to private labels and national brands, which is the focus of our empirical application. Further, the Manufacturer Stackelberg assumption used in both models have often been used in more recent research as well (*e.g.*, Narasimhan and Wilcox 1998). Second, since each of these models assumes a linear demand structure, we examine how well the linear demand specification characterizes actual market behavior by comparing them to a flexible non-linear functional form.[1] In assessing the assumptions that underlie these models, we are not asserting *a priori* that these theoretical models are necessarily deficient in any way. Rather, we seek to demonstrate how empirical analysis can be used to complement existing theoretical work and guide future research towards assumptions that are consistent with empirical observation.

The first portion of the paper is analytical in nature and it proceeds as follows. We begin by presenting the Choi (1991) and Raju, *et al.* (1995) models in turn, deriving the associated reaction functions for each under strategic profit maximizing behavior. With an eye to our empirical application, we focus on two brands, one a national brand and one a private label. We then demonstrate that the Raju, Sethuraman and Dhar (1995) and the Choi (1991) Manufacturer Stackelberg models can be represented as special cases of a more general class of mark-up models. This provides a direct connection between the theoretical framework used in both papers and the mark-up assumptions made in much of the empirical IO literature (*e.g.*, Kadiyali, Vilcassim and Chintagunta 1999, Cotterill, Putsis and Dhar 1999). Empirical tests are then developed for Manufacturer Stackelberg conduct and the use of proportional mark-up rules within the channel. In order to address the assumption of linear demands, we then present a general non-linear functional demand specification based upon the Linear Approximate Almost Ideal Demand System (LA/AIDS, Cotterill, Putsis and Dhar 1999). The reaction function associated with this non-linear model is sufficiently general to permit Manufacturer Stackelberg behavior within the channel, thereby making it directly comparable to the Choi (1991) and Raju, *et al.* (1995) models.

In our empirical application, we estimate demands and price reactions simultaneously, comparing the results obtained for each of the three models applied to data for six individual categories: milk, butter, bread, pasta, margarine and instant coffee. The empirical results generally support the assumptions of proportional mark-up behavior by retailers and Manufacturer Stackelberg conduct within the channel. While this lends support to the assumptions made in a number of theoretical models addressing channel behavior, we reject linear demands in a favor of a more flexible non-linear form.

2. Estimating and Comparing the Choi (1991) Manufacturer Stackelberg, Raju, *et al.* (1995) and LA/AIDS (Non-Linear) Models

Modeling the interaction between national brands and private labels is especially challenging because, unlike competition between two national brands, there is a vertical relationship between national brand manufacturers and retailers. As a result, one needs to be concerned about the vertical as well as the horizontal nature of competitive interaction. Choi (1991) analyzes linear demands under three different

1. We note that empirical work in this area (*e.g.*, Putsis and Dhar 1998, Kadiyali, Chintagunta and Vilcassim 1997) has also generally assumed linear demands.

behavioral assumptions for the vertical pricing game. These models assume that manufacturers act as Stackelberg leaders within the channel (MS), retailers act as Stackelberg leaders within the channel (RS), and retailers and manufacturers play a vertical Nash (VN) game within the channel, respectively. Alternatively, Raju, *et al.* (1995) use a restricted version of Shubik's linear-form demand model and specify Manufacturer Stackelberg conduct. In the next section, we begin by deriving the retail reaction functions for the Choi (1991) Manufacturer Stackelberg and the Raju, *et al.* (1995) models. When these reaction functions are combined with a linear demand structure, we have a fully estimable demand and supply system that allows us to test for alternative demand forms and vertical channel behavior.

a. The Choi (1991) Manufacturer Stackelberg (MS) Model:

Choi (1991) assumes that the vertical game has 3 players. In our context, this implies a national brand manufacturer, a private label manufacturer, and a retailer that sells both the private label product and the national brand. Following in the tradition of McGuire and Staelin (1983) and Jeuland and Shugan (1988), Choi specifies linear demand functions that allow for product differentiation (we retain his notation here):

$$q_i = a - bp_i + \gamma p_j, \quad \forall\ i, j = 1, 2, \quad j \neq i \qquad (1)$$

where q_i is demand for brand i at price p_i given that the price of the other brand j is p_j. Without loss of generality, we designate brand 1 as the national brand and brand 2 as the private label. The retailer maximizes category profits, Π_R by choosing values of p_1 and p_2 for given wholesales prices for the product, w_1, w_2:

$$\underset{p_1,\, p_2}{MAX}\ \Pi_R = (p_1 - w_1)\, q_1(p_1, p_2) + (p_2 - w_2)\, q_2(p_1, p_2) \qquad (2)$$

The two manufacturers maximize their profits as follows (c_1 and c_2 denote the respective manufacturer marginal costs):

$$\underset{w_i}{MAX}\ \Pi_{mi} = (w_i - c_i)\, q_i(p_1, p_2) \qquad i = 1,2 \qquad (3)$$

The retailer's first order conditions (FOC) are:

$$-2bp_1 + 2\gamma p_2 + bw_1 - \gamma w_2 + a = 0 \qquad (4)$$

[illegible] (5)

The manufacturer's first order conditions (FOC) are:

National Brand: $a - bp_1 + \gamma p_2 - bw_1 + bc_1 = 0$ (6)

Private Label: $a - bp_2 + \gamma p_1 - bw_2 + bc_2 = 0$

This approach produces six endogenous variables (q_1, q_2, p_1, p_2, w_1 and w_2) and six equations (2 demand equations, 2 retailer FOC, and 2 manufacturer FOC). Assuming Manufacturer Stackelberg conduct (the national brand manufacturer as the leader) allows one to solve these six equations for reduced form equations that give the equilibrium values of the endogenous variables as functions of the exogenous variables. In principal, one can estimate the parameters of the model from these reduced form equations; alternatively, one can estimate the six "structural" equations, provided that the data were available.

Since data on wholesale prices are not generally available, we tack a different tack and reduce the structural estimation problem to four equations involving the four available endogenous variables ($q_1\ q_2, p_1\ \ p_2$) by using the same information from the retailer's price reaction functions for p_1, p_2 that one uses to solve for reduced form equations in the Stackelberg game. The retailers price reaction for p_1 as derived from the retailer FOC (equations 4 and 5) is:

$$p_1 = \frac{w_1}{2} + \frac{a}{2(b-\gamma)} \tag{7}$$

Note that this equation implies that the manufacturer actually determines the retail level price for his brand when w_1 is set. Thus one can restate the manufacturer's profit maximization problem with p_1 as the manufacturer's choice variable by solving (7) for w_1 as a function of p_1:

$$w_1 = 2p_1 - a / (b - \gamma) \tag{8}$$

Substituting it into equation 3 (for $i = 1$) one obtains:

$$\underset{p_1}{MAX}\ \Pi_m = (2p_1 - \frac{a}{b-\gamma} - c_1)\ q_1(p_1\ p_2) \tag{9}$$

The corresponding FOC is:

$$2a - 4bp_1 + 2\gamma p_2 + \frac{ab}{b-\gamma} + bc_1 = 0 \tag{10}$$

Solving this equation for p_1 gives the price reaction function between the manufacturer-controlled retail level brand price and the retail-controlled private label price. This reaction captures the manufacturer's best response for setting p_1 when retailers choose a value for p_2:

$$p_1 = \frac{\gamma}{2b} p_2 + \frac{a}{2b} + \frac{a}{4(b-\gamma)} + \frac{c_1}{4} \tag{11}$$

Similarly, the retailer's price reaction function for p_2 can be derived by solving the retailer's other first order condition for p_2. This gives the retailer's vertical price reaction function:

$$p_2 = \frac{w_2}{2} + \frac{a}{2(b-\gamma)} \tag{12}$$

Solving for w_2 by substituting this into equation 3 (for $i = 2$), we obtain:

$$\underset{p_2}{MAX}\ \Pi_{PL} = (2p_2 - \frac{a}{b-\gamma} - c_2)q_2(p_1\ p_2) \tag{13}$$

The retail-level price reaction function between the national brand and private label manufacturers is:

$$p_2 = \frac{\gamma}{2b} p_1 + \frac{a}{2b} + \frac{a}{4(b-\gamma)} + \frac{c_2}{4} \tag{14}$$

This provides us with an empirically estimable model that consists of the two demand equations (Equation 1, for i and j) and the two retail level brand price reaction functions (equations 11 and 14). With appropriate cross equation restrictions, we can estimate the parameters, $a, b, \gamma,$ in addition to the demand and price reaction elasticities. One can also use equation (8) to recover an estimate for w_1, the unobserved wholesale price for the national brand, and equation (12) to recover an estimate for w_2, the unobserved wholesale price for the private label.

We also note that in the event that the private label manufacturer has no market power vis à vis the retailer, and sells its product at a price equal to marginal cost, then $w_2 = c_2$. The private label manufacturer's profit maximization problem vanishes and equation (14) is replaced by equation (12) with $w_2 = c_2$, giving the following price reaction curve:

$$p_2 = \frac{c_2}{2} + \frac{a}{2(b-\gamma)} \tag{15}$$

Thus, in the competitive private label case, the retail level price reaction functions are asymmetric – national brand prices react to changes in private label prices, while private label prices are exogenously determined.

b. The *Raju, et al. (restricted Shubik) Model*

For the Raju *et al.* (1995) model, our structural model consists of two demand equations and the asymmetric retail price reaction functions as follows:[2]

$$q_1 = a_1 + bp_1 + \gamma p_2 \qquad (16)$$

$$q_2 = a_2 + bp_2 + \gamma p_1 \qquad (17)$$

$$p_1 = \frac{\gamma}{2b} p_2 + \frac{a_1}{2b} + \frac{ba_1 + \gamma a_2}{4(b^2 - \gamma^2)} + \frac{c_1}{4} \qquad (18)$$

$$p_2 = \frac{c_2}{2} + \frac{\gamma a_1 + b_1 a_2}{b^2 - \gamma^2} \qquad (19)$$

Note that the coefficient on private label price in the national brand price reaction equation (18) is identical to the Choi (1991) coefficient in (11). The only differences between the Choi (1991) Manufacturer Stackelberg and the Raju, *et al.* (1995) models are that the former relaxes the identical intercept assumption in the demand system and assumes that private label manufacturers are competitive. This allows us to nest the Choi (1991) and Raju, *et al.* (1995) models, producing a convenient test of two alternative views of demand structure and manufacturer-retailer interaction.

c. The Choi (1991) and Raju, et al. (1995) Models within a General Class of Mark-up Models:

Here, we modify the maximization above by assuming that retailers use mark-up pricing in a Manufacturer Stackelberg environment. If retailers use a generalized mark-up for national brands:

$$p_1 = m_1 w_1 + m_o \qquad (20)$$

where m_1 and m_o are proportional and fixed mark-up parameters respectively. Solving this price relation for w_1 gives:

$$w_1 = k_1 \; p_1 \; - k_0 \qquad (21)$$

where $k_1 = (1/m_1)$ and $k_0 = (m_0/m_1)$. Substituting (21) into the manufacturer' profit maximization problem in (3), one can obtain the following retail level price reaction equation for the Choi (1991) demand system with Manufacturer Stackelberg conduct under generalized mark-up behavior by retailers:

2. We simplify presentation of the restricted Shubik demands here to facilitate comparison with the Choi (1991) specification. Under the Raju, *et al.* restricted Shubik demands, the national brand demands are expressed as follows: $q_1 = 1/(1+\alpha)\,[\,1 - p_1 + \delta\,(p_2 - p_1)] = [1/(1+\alpha)] - [(1+\delta)/(1+\alpha)]\,p_1 + [\delta\,/\,(1+\alpha)]\,p_2$, which is simplified to equation 16 above. For the private label, the only difference is that the intercept, a_2 above, is equal to $[a\,/\,(1+a)]$, as opposed to $[1/(1+\alpha)]$ for the national brand. The (accordingly) appropriate demand restrictions are incorporated in estimation.

$$p_1 = \frac{\gamma}{2b} P_2 + (\frac{a}{2b} + \frac{k_o}{ak_1}) + \frac{c_1}{2k_1} \qquad (22)$$

Note that the reaction curve slope for the generalized mark-up model in (22) is identical to the slope ($\gamma/ 2b$) for the reaction curve under strategic profit maximization in (11), and that in estimation k_1 is subsumed in the generalized cost term c_1. Since in our empirical work we employ instruments for marginal costs, we cannot identify k_1. However, we note that if:[3]

$$\frac{k_o}{k_1} = \frac{a^2}{4(b-\gamma)} = m_0 \text{, and } k_1 = 2, \qquad (22')$$

then generalized mark-up behavior is identical to profit maximizing behavior in a Choi (1991) Manufacturer Stackelberg game (since equation 22 reduces to 11). Alternatively, under proportional mark-up pricing, $m_0 = 0$ hence $k_o = 0$ and the reaction function reduces to:

$$p_1 = \frac{\gamma}{2b} p_2 + \frac{a}{2b} + \frac{c_1}{2k_1} \qquad (23)$$

Thus, if the intercept in the linear national brand reaction function is equal to ($a / 2b$), then the proportional mark-up model holds for the Choi (1991) specification. Note that if the private label manufacturers also play a Choi (1991) Manufacturer Stackelberg game, an analogous set of reaction functions exist. The mark-up parameters, however, need not be identical to those for the national brand.

Similarly, we can derive an analogous set of conditions in the event that the demand specification is consistent with Manufacturer Stackelberg behavior under restricted Shubik demands as in Raju, *et al.* (1995). In this case, the reaction function for the national brand under the generalized mark-up model is:

$$p_1 = \frac{\gamma}{2b} p_2 + \frac{a_1}{2b} + \frac{k_0}{2k_1} + \frac{c_1}{2k_1} \qquad (24)$$

For this to be consistent with profit maximizing behavior (*i.e.*, identical to 18) one must have:

$$\frac{k_0}{k_1} = \frac{ba_1 + \gamma a_2}{2(b^2 - \gamma^2)}, \quad \text{and} \quad k_1 = 2. \qquad (25)$$

3. As pointed out by Genesove and Mullin (1998), the requirement that $k_1 = 2$ is a direct consequence a linear demand schedule, which implies that exactly 50% of any change in cost (c_1 to the manufacturer and w_1 for the retailer) is passed on. Thus, due to double marginalization, only ¼ of a change in c_1 (see equation 11) and c_2 (equation 14) is eventually passed on to the consumer. As pointed out by Genesove and Mullin (1998) and by Cotterill, Putsis and Dhar (1999), what seems like a simple demand assumption (linearity), actually places a rather restrictive assumption (non-strategic passthrough of 50%) on channel pricing behavior.

We use these relationships in the next sub-section to develop tests for assessing a) whether the demand structure observed is consistent with the Choi (1991) or Raju, *et al.* (1995) specifications (or with neither), b) if the vertical channel relationship is consistent with Manufacturer Stackelberg behavior, and c) proportional mark-up conduct by retailers.

d. Testing for Choi (1991) versus Raju, et al. (1995) Restricted Shubik Demand Structure, Manufacturer Stackelberg, and Mark-up Conduct

The relationships detailed above provide for a series of convenient tests of demand structure and within channel behavior. To demonstrate, we first estimate the following linear demand and price reaction system:

$$q_1 = A_{10} - A_{11} p_1 + A_{12} p_2 + A_{13} D \tag{26}$$

$$q_2 = A_{20} - A_{21} p_2 + A_{22} p_1 + A_{23} D \tag{27}$$

$$p_1 = R_{10} + R_{11} p_2 + R_{12} c_1 + R_{13} D \tag{28}$$

$$p_2 = R_{20} - R_{21} p_1 + R_{22} c_2 + R_{23} D, \tag{29}$$

where all variables are defined earlier except for c_1 and c_2, which are instruments for unobserved marginal costs, and D, which denotes a series of demand shift variables needed for empirical analysis.

To begin, we note that both the Choi (1991) and Raju, *et al.* (1995) demand models assume symmetric price response – specifically, they assume that the own and cross price responses are the same for private labels and national brands (see equations 1, 16 and 17), respectively. Thus, if *either* demand model is to be supported empirically, the following *must* hold:

$$A_{11} - A_{21} = 0 \tag{30a}$$

$$A_{12} - A_{22} = 0 \tag{30b}$$

If we reject the "symmetry" restrictions (30a) and (30b) empirically, we conclude that the demand structure is consistent with neither the Choi (1991) linear or Raju *et al*. (1995) restricted Shubik demands. In the event that we are unable to reject these symmetry restrictions, we then proceed to test whether the demand structure is more consistent with the Choi (1991) or Raju, *et al.* (1995) specifications. In order to do this, we note that as discussed in section 2b, the Choi (1991) demand model imposes the additional assumption of equal intercepts for private labels and national brands. Thus, if:

$$A_{10} - A_{20} = 0 \tag{31}$$

then the system is consistent with the Choi (1991) demand specification, and if $A_{10} - A_{20} \neq 0$ then it is consistent with Raju, *et al*. (1995) demand specification.

To test for Manufacturer Stackelberg conduct, note that thus far we have considered two forms of retailer behavior in a Manufacturer Stackelberg environment under the Choi (1991) and Raju, *et al*. (1995) demand models. First, we considered the case of strategic profit maximizing retailers (*e.g*., equations 11 and 18 for national brands in the Choi and Raju, *et al*. models, respectively) and then we considered the use of proportional mark-up behavior by retailers (*e.g*., equations 23 and 24 for national brands in the Choi and Raju, *et al.* models, respectively). Note that for both forms of retailer behavior, the price coefficient in each price reaction equation equals γ / 2b (see equations 11, 18, 23, 24). Thus, for national brands, equation (32) *must* hold (and analogously, equation 33 for private labels) if either model is to be consistent with Manufacturer Stackelberg conduct within the channel:[4]

Manufacturer Stackelberg Conduct, National Brands:

$$R_{11} - \frac{A_{12}}{2A_{11}} = 0 \tag{32}$$

Manufacturer Stackelberg Conduct, Private Labels:

$$R_{21} - \frac{A_{22}}{2A_{21}} = 0 \tag{33}$$

Imposing the restrictions in (32) and (33) provides a test for a Manufacturer Stackelberg relationship between manufacturers and retailers for national brands and private labels, respectively.[5] We also note that if:

$$R_{21} = 0 \tag{34}$$

and

$$R_{20} = \frac{A_{20}}{2(A_{21} - A_{22})}, \tag{35}$$

4. We note that it can be shown that this test is more general and is not dependent upon the specific assumptions made in the Choi (1991) or Raju, *et al*. (1995) demand models – that is, it does not necessitate our accepting either demand model. Indeed, for certain categories (butter, margarine, and instant coffee), we reject the Choi and Raju, *et al*. demand models, but are able to accept Manufacturer Stackelberg conduct.

5. We note that in developing these tests, we examine only the price coefficients in the price reaction equations (see, e.g., equations 11, 18, 23, 24 for national brands), although more generally, we would need to examine the intercept terms as well. However, in the empirical analysis discussed below, for each category where we observe Manufacturer Stackelberg behavior, we also find proportional markup conduct (equations 36 and 37). Thus, in the interest of parsimony, we do not include the intercept term (*e.g*., as in restrictions 36 and 37 below) in the Manufacturer Stackelberg tests presented here. Extending these to the more general case that also allows us to test retailer profit maximizing behavior (see equations 11 and 18 for national brands) is trivial.

then the private label reaction function is consistent with (15), suggesting that private label manufacturers sell to retailers at competitive prices (*i.e.*, at marginal cost).

If the retailer operates under a proportional mark-up rule, the following relationship must also hold (see the discussion in section 2c following equation 23):

Proportional Mark-up Behavior, National Brands:

$$R_{10} - \frac{A_{10}}{2A_{11}} = 0 \tag{36}$$

Proportional Mark-up Behavior, Private Labels:

$$R_{20} - \frac{A_{20}}{2A_{21}} = 0 \tag{37}$$

Thus, if the restriction (36) holds, this suggests that the data are consistent with retailers applying a proportional mark-up to the national brand manufacturer's wholesale prices (and analogously for private labels in 37). Note that it is possible for us to observe behavior consistent with Manufacturer Stackelberg conduct for national brands and private labels, for just one, or for neither. Similarly, proportional mark-up behavior can be observed for national brands and private labels, for just one, or for neither. However, note that the tests for proportional mark-up behavior are conditional on our first accepting Manufacturer Stackelberg conduct. Thus, if we reject Manufacturer Stackelberg conduct (via equations 32 and 33), then the general model does not hold and the tests of proportional mark-up behavior make little sense in this context. Note that in this instance, this doesn't imply that we reject proportional mark-up behavior since proportional mark-up behavior may simply exist within a vertical arrangement other than a Manufacturer Stackelberg one (we mark such instances with an asterisk in Table 1 below). Finally, for each empirical test, we impose the restriction and test versus the unrestricted model using a likelihood ratio test.

e. Comparing with a Non-Linear Formulation – The LA/AIDS model

All of the tests above are based upon the linear demand specification. However, it is not at all clear that the linear specification provides the best fit to the data. In this section, we present an alternative non-linear demand-side specification (LA/AIDS) that we will compare to the general linear model (equations 26 to 29) using non-nested hypothesis tests. We do this for each of the six individual categories. This incremental step provides information on the appropriateness of the linear demand structure.

In previous research, Cotterill, Putsis and Dhar (1999) specified a four-equation system based upon the LA/AIDS, a flexible (and non-linear) demand system originally proposed by Deaton and

Muellbauer (1980a, 1980b). The four equations consist of two demand equations (equation 38) and two price reaction equations (equation 39). Based on the results discussed below, we develop this model assuming Manufacturer Stackelberg behavior within the channel (the model is sufficiently general to allow for strategic profit maximizing, general or proportional mark-up behavior by retailers). Adding superscripts for market i (i = 1, .., 59) and category j (j = 1,…,125), the LA/AIDS system is specified as:

$$S_1^{ij} = \alpha_{10} + \alpha_{11} \ln p_1^{ij} + \alpha_{12} \ln p_2^{ij} + \alpha_{13} \ln (E^{ij}) + \alpha_{14} D^{ij}$$
$$S_2^{ij} = \alpha_{20} + \alpha_{21} \ln p_1^{ij} + \alpha_{22} \ln p_2^{ij} + \alpha_{23} \ln (E^{ij}) + \alpha_{24} D^{ij} \quad (38)$$

and

$$\ln p_1^{ij} = \beta_{10} + \beta_{11} \ln p_2^{ij} + \beta_{12} D^{ij} + \beta_{13} E^{ij} + \beta_{14} c_1^{ij}$$
$$\ln p_2^{ij} = \beta_{20} + \beta_{21} \ln p_1^{ij} + \beta_{22} D^{ij} + \beta_{23} E^{ij} + \beta_{24} c_2^{ij} \quad (39)$$

Where, in addition to the variables specified earlier,

S_1^{ij} = dollar market share of the national brand,

S_2^{ij} = dollar market share of the private label,

E^{ij} = total per capita expenditure divided by Stone's price index, which is equal to $S_1^{ij} \ln p_1^{ij} + S_2^{ij} \ln p_2^{ij}$

Since the assumptions regarding within-channel behavior in this framework (Manufacturer Stackelberg conduct) can be represented as part of the same general class of models (Section 2c above), it provides a convenient "null" model to compare to the Choi (1991) and Raju, *et al.* (1995) models. Note that the only point of difference between the two models discussed earlier (Choi 1991, Raju, *et al*. 1995) and the specification (38 and 39) is the non-linear demand specification.

3. Empirical Estimation

a. Data

The empirical analysis is conducted using IRI data for six individual categories (milk, butter, bread, pasta, margarine and instant coffee) across 59 local geographic markets for 1991 and 1992. These data were merged with independent data from *Progressive Grocer* on the demographic characteristics of the IRI geographic markets. Consistent with previous work in the private label area (*e.g.*, Sethuraman and Mittelstaedt 1992; Slade 1995; Putsis and Dhar 1998), aggregate branded and private label variables were created for each category across all markets. National brand price, feature, display, and price reduction variables are volume as opposed to dollar market share weighted averages.[6] For each model, a series of demand shift variables (D^{ij}), cost shift variables (c^{ij}) and a series of variables controlling for structural market characteristics (*e.g.*, concentration) were included in the analysis. Chart 1 includes a list of the variables used in the empirical analysis.

< Chart 1 about here >

b. Empirical Methodology

To summarize the discussion above, we presented and estimated three potential models of pricing conduct employing three-stage least squares, using both nested and non-nested tests:

- Choi's (1991) linear demand model with Manufacturer Stackelberg (MS) conduct,
- Raju, Sethuraman and Dhar's (1995) model specifying restricted Shubik demands with Manufacturer Stackelberg conduct, and
- LA/AIDS (non-linear) demands assuming Manufacturer Stackelberg conduct.

We proceeded as follows. First, using the tests described in section 2d (restrictions 30 and 31), we tested whether the Choi (1991) or Raju demands more closely represent the underlying demand structure, allowing for the possibility that neither was consistent with the data. Second, in order to test the assumptions regarding channel behavior for each of the models studied, we test for Manufacturer Stackelberg conduct and proportional mark-up behavior (restrictions 32, 33, 36, 37). Third, using these results (Choi or Raju; Manufacturer Stackelberg or not; proportional mark-up or not), we then tested the general linear demand specification (equations 26 to 29) against the LA/AIDS non-linear form using non-nested hypothesis tests (Davidson and MacKinnon 1981, Balasubramanian and Jain 1994). This provided a direct test of whether or not the non-linear form (assuming essentially the same channel structure) fits better for each of the six categories, and if it does indeed fit better, how much better. If, at the conclusion of our empirical analysis, we are able to provide cross-category empirical support for the within-channel assumptions made by Choi (1991) and by Raju, *et al.* (1995), and if we are not able to improve the

6. For example, aggregate private label and national brand variables were created for share, price and price reduction. Private label (national brand) share is sum of all private label (national) brands in the ith market, jth category. Private label (national brand) price is the volume-weighted average price of all private labels (national brands) in the ith market, jth category. The two price reduction variables are volume-weighted percent price reduction for all private label and branded products, respectively. Thus, for price and share, we have four aggregate variables: total branded share, total private label share, volume-weighted average price of national brands, and the volume-weighted average price of private label products. Also, note that the choice of variables was influenced by data availability. For example, no coupon information was available, while average age, income and percent Hispanic were the only local demographic variables available.

demand-side fit by moving to a non-linear form, we would argue that this provides a great deal of support for the assumptions made in these and related models.

4. Empirical Results

Table 1 presents the results from the hypotheses tests used to determine a) whether the Choi (1991) or Raju, *et al.* (1995) demand model best fit the data, and b) which form of within channel behavior best fits the data (Section 2d above).

< *Table 1 about here* >

Examining Table 1, we can see that the Choi (1991) demand model fits best for the bread category, while the Raju, *et al.* (1995) modified Shubik demands are more consistent with the milk and pasta categories. In fact, the milk and pasta are consistent with all of the central assumptions of the Raju, et al. (1995) model, while the bread category fits all key Choi (1991) MS assumptions. However, we reject both models in the butter, margarine and instant coffee categories. Regarding vertical conduct, out of 12 tests for Stackelberg price reaction coefficients (6 for national brands and 6 for private labels), all but 3 are consistent with Stackelberg behavior within the channel. For the 9 cases where we accept Manufacturer Stackelberg conduct, *all 9* are consistent with proportional mark-up behavior within the channel.

Note that the inability to reject Stackelberg and proportional mark-up behavior for almost all within channel pricing behavior (and for essentially all private label pricing) is consistent with the assumptions made in much of the previous theoretical and empirical research. For example, the assumptions of Manufacturer Stackelberg behavior within the channel used in previous theoretical work (*e.g.*, Choi 1991, Raju, Sethuraman and Dhar 1995, Narasimhan and Wilcox 1998, Cotterill, Putsis and Dhar 1999) may be quite reasonable. Further, the use of proportional mark-up assumptions in the empirical IO literature (*e.g.*, Kadiyali, Vilcassim and Chintagunta 1999) may be consistent with observed behavior as well.

Can we say the same about the linear demand structure? We present two sets of results. Table 2 presents the estimated demand and price reaction elasticities for the LA/AIDS functional form. These parameter estimates have not only a great deal of face validity, but are also consistent with previous research on a number of dimensions. For example, Tellis (1988) in a meta-analysis of reported demand elasticities, found the mean price elasticity of demand to be -1.71, consistent with the national brand elasticities reported in the first row of Table 2. In addition, we find significant asymmetric price response

– the estimated private label own price elasticities are higher in most categories. However, this asymmetry is reversed in the butter category, which is consistent with recent work by Bronnenberg and Wathieu (1996). In terms of the price reaction elasticities, the price reactions of national brands were small in magnitude, with the highest price reaction by national brands occurring in the category with one of the highest private label shares (margarine). Overall, the reported price reactions are very close to those reported by Lambin (1976) and others (*e.g.*, Hanssens, Parsons and Schultz 1990, pp. 201-210).

< *Tables 2 and 3 about here* >

Alternatively, the results for the Choi (1991) and Raju, *et al.* (1995) linear demand specifications presented in Table 3 show fewer significant coefficients and a great deal more volatility in the parameter estimates. While there is some consistency between the magnitude of the *significant* demand elasticities for the linear and the LA/AIDS specifications, there are not many significant parameter estimates in Table 3. For both the linear demand and price reaction elasticities, a number of parameter estimates are outside of the range reported in other studies. For example, the estimated price reaction elasticity of 2.1 (which is significant at $\alpha = .01$) for private labels in the pasta category not only *seems* high, it is inconsistent with previous research (*e.g.*, Lambin 1976). We conjecture that the relative stability of the parameter estimates and the high number of significant coefficients in the LA/AIDS system are due in large part to the highly flexible form of the LA/AIDS specification.

Finally, we tested the two demand structures more formally. Specifically, we tested for the possibility of a simpler linear functional form by comparing the LA/AIDS specification to a linear form using a non-nested P-E test (Davidson and MacKinnon 1981). Balasubramanian and Jain (1994) suggest that the choice of non-nested test should be guided by the circumstances surrounding the test (see, *e.g.*, their Table 7 for the appropriateness of using the P-E test in the current application). Jain and Vilcassim (1989) demonstrate that the sample size requirements for the P-E test may be less stringent than that required for Lagrange multiplier tests, suggesting that that it is particularly relevant in our application. We employ it as detailed in Greene (1997, pp. 459-462). The results for the demand specification were even more conclusive than those for within-channel structure discussed above. For all six categories, the P-E test cleanly rejected the null of a linear model at $p << .01$.

5. Conclusions, Limitations and Future Research

In terms of within-channel behavior, using the six categories examined in our analysis, assumptions regarding Manufacturer Stackelberg and proportional mark-up behavior within the channel are generally supported. This should provide comfort to theoretical and empirical researchers alike. On the theoretical side, this suggests that assumptions regarding within channel Stackelberg behavior (*e.g.*, Raju, *et al.* 1995) may be reasonable characterizations of actual channel behavior. For empirical research, our results also suggest that the simplifying assumption of the use of a proportional mark-up rule (*e.g.*, as used in Kadiyali, Vilcassim and Chintagunta 1999 and Cotterill, Putsis and Dhar 1999), which is often needed when data on wholesale prices are not available, may also be reasonable.

On the demand side, despite some restrictive demand-side assumptions and a seemingly inflexible functional form, the Choi (1991) and Raju, *et al.* (1995) models did not fare poorly. We were able to determine which of the two best fit the data and derive a number of statistically significant and reasonable elasticities. However, the volatility of the parameter estimates is disconcerting. The large number of insignificant coefficients leaves a researcher without information on key parameter values. Further, price reaction elasticities over 1.0 seem questionable even if statistically significant. Further, as demonstrated elsewhere (Cotterill, Putsis and Dhar 1999, Genesove and Mullin 1998), linear demands place some rather restrictive assumptions on channel behavior. For example, assuming a linear demand implies a fixed and constant pass-through rate within the channel, imposing a rather restrictive constraint on vertical strategic behavior. In contrast, the LA/AIDS framework introduced above provides us with a flexible functional form that performs well on a number of individual categories and does not require similarly restrictive assumptions on vertical behavior. Non-nested tests suggested that the improvement in fit in moving to the non-linear form was significant. All of this suggests that further theoretical and empirical research examining the implications of linear demand structures for channel behavior building on the work of Lee and Staelin (1997) and Moorthy and Fader (1990) is clearly needed.

This last point illustrates the use of empirical analysis of the type conducted here. Empirical analysis should be viewed as a complement to theoretical research, not as a challenge to it. Empirical research can guide which aspects of the theory warrant further investigation, and as such it should not be limited to testing the implications of the theory. In the analysis above, we find that previous assumptions of Manufacturer Stackelberg behavior and proportional mark-up conduct are generally reasonable assumptions. In contrast, we find that linear demands do not fit nearly as well as non-linear forms, result in questionable demand-side parameter estimates, and place rather restrictive assumptions on both demand and channel behavior. Overall, these results should provide comfort to both theoretical research in the channels area (*e.g.*, Raju, Sethuraman and Dhar 1995) that has assumed Manufacturer Stackelberg behavior, and empirical research that has assumed a proportional mark-up rule (*e.g.*, Kadiyali, Vilcassim and Chintagunta 1999). However, the results suggest that assumptions of a linear demand should be viewed with some caution.

There are a number of limitations of this research. For example, future research should examine additional product categories and models. We only examine six categories. A more extensive examination across multiple categories and a deeper understanding of the cross-category variation in observed channel interaction is needed. In addition, we examine a very limited set of models and demand structures. This was intentional, with the objective of keeping the analysis focused and rigorous. However, this clearly limits our ability to generalize our findings to other assumptions of channel behavior, other models of channel relationships and alternative demand functional forms. Future research should examine how robust *our* findings are to the forms considered. Perhaps most importantly, we consider only one non-linear form, the LA/AIDS specification. Given the restrictions placed on vertical conduct as a result of a linear demand specification, a comprehensive empirical investigation of non-linear forms, channel behavior and related passthrough rates is needed. Nonetheless, we believe that our approach illustrates how empirical analysis can be used effectively to examine the underpinnings of theoretical models and to guide future theoretical and empirical research.

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Chart 1. Definitions for Variables Used in the Analysis

(All Variables Defined for the ith market, jth category)

	*Dependent Variables**
BRSHARE	Aggregate share of category expenditure for national brands
PLSHARE	Aggregate share of category expenditure for private label products
BRPRICE	Natural log of the price of the national brand
PLPRICE	Natural log of the price of the private label product
	Demand-Shift Variables (D^{ij})
EXPENDITURE	Natural log of per capita category expenditures deflated by Stone's price index
BRFEATURE	Percent of national brands sold with feature advertising
BRDISPLAY	Percent of national brands sold with displays and point-of-sale promotion
PLFEATURE	Percent of private label products sold with feature advertising
PLDISPLAY	Percent of private label products sold with displays and point-of-sale promotion
BRPRICEREDN	Weighted percent average price reduction, national brands
PLPRICEREDN	Weighted percent average price reduction, private label products
PLDISTN	Private label average distribution
INCOME	Natural log of the average household income in the local market
HISPANIC	Percent of population in the local market of Hispanic decent
AGE	Natural log of the average age of the local market population
	Cost Variables (c^{ij})
BRVOLPUN	Natural log of average volume (weight) per package unit sold for national brand
PLVOLPUN	Natural log of average volume (weight) per package unit sold for private label
	Variables Controlling for Structural Market Characteristics
HERFINDAHL	Herfindahl index of brand concentration in the local market
GROCCR4	Percentage of all grocery sales by the top four grocery chains in the local market

* Price rather than the natural log of price, and quantity rather than share, are used in the Choi (1991) and Raju, *et al.* (1995) models.

Table 1. Demand Structure, Manufacturer Stackelberg, and Proportional Mark-up Test Results for Individual Categories, Linear Model[1]

	Milk	Butter	Bread	Pasta	Margarine	Inst. Coffee
			Demand Structure			
			(Symmetry Conditions)			
(30a) Own-price	Yes	Yes	Yes	Yes	No	No
(30b) Cross-price	Yes	No	Yes	Yes	Yes	No
			(Choice of Model)			
Choi, Raju or Neither (Equation 31)	Raju	Neither	Choi	Raju	Neither	Neither
			Manufacturer Stackelberg Conduct?			
i) National Brand (Equations 32)	Yes	Yes	Yes	Yes	No	No
ii) Private Label (Equations 33)	Yes	Yes	Yes	No	Yes	Yes
			Proportional Mark-up Conduct?			
i) National Brand (Equation 36)	Yes	Yes	Yes	Yes	*	*
ii) Private Label (Equation 37)	Yes	Yes	Yes	*	Yes	Yes

[1] All restrictions are tested using a likelihood ratio (LR) test at the 5% significance level.
* As noted in the text, Manufacturer Stackelberg conduct required for proportional mark-up test.

Table 2. Demand and Reaction Elasticities for Individual Product Categories, LA/AIDS Model

	Milk	Butter	Bread	Pasta	Margarine	Inst. Coffee
BR Own Price Elasticity	-1.63 (-4.20)**	-1.82 (-3.19)**	-1.80 (-9.66)**	-1.48 (-13.90)**	-1.16 (-21.63)**	-1.05 (-47.06)**
PL Own Price Elasticity	-1.22 (-2.81)**	-2.93 (-4.47)**	-1.66 (-4.66)**	-2.31 (-3.38)**	-5.86 (-6.60)**	-0.100 (-0.318)
BR Cross Price Elasticity	0.458 (0.513)	1.39 (2.94)**	0.234 (1.86)	0.206 (1.91)	0.474 (5.47)**	-0.043 (-2.86)**
PL Cross Price Elasticity	0.308 (1.63)	1.14 (1.44)	2.26 (4.30)**	3.04 (4.50)**	1.66 (3.01)**	1.05 (2.26)*
BR Price Reaction Elasticity	-0.600 (-1.64)	0.401 (3.40)**	0.322 (3.39)**	1.25 (0.932)	1.06 (3.69)**	0.070 (1.07)
PL Price Reaction Elasticity	0.175 (2.10)*	0.777 (4.53)**	0.321 (0.84)	1.01 (2.89)**	0.231 (0.776)	-0.083 (-0.518)
Average BR Share	.30	.54	.62	.81	.84	.94
NOBS	116	112	118	118	118	108

BR = National Brand, PL = Private Label (t-statistics in parentheses)

** significant at the 1% level. * significant at the 5% level

Table 3. Demand and Reaction Elasticities for Individual Product Categories, Linear Model

	Milk	Butter	Bread	Pasta	Margarine	Inst. Coffee
Selected Demand Structure	Raju	Choi	Choi	Raju	Choi	Raju
BR Own Price Elasticity	-2.74 (-6.06)**	-0.453 (-0.676)	-0.415 (-0.925)	-1.12 (-8.40)**	-1.31 (-12.95)**	-0.907 (-18.37)**
PL Own Price Elasticity	-0.831 (-1.62)	-0.245 (-0.245)	0.060 (0.084)	-0.609 (-1.02)	-7.78 (-5.34)**	-0.009 (-0.028)
BR Cross Price Elasticity	-0.059 (-0.057)	-0.020 (-0.032)	-0.472 (-1.83)	-0.141 (-1.33)	0.564 (3.80)**	-0.135 (-3.91)**
PL Cross Price Elasticity	0.769 (3.40)**	-1.93 (-1.82)	-1.73 (-1.38)	0.481 (0.641)	4.18 (3.95)**	1.17 (2.61)**
BR Price Reaction Elasticity	-0.361 (-1.42)	0.551 (5.16)**	0.307 (2.25)*	1.19 (0.400)	1.44 (4.28)**	0.039 (0.603)
PL Price Reaction Elasticity	0.199 (2.39)*	0.731 (5.21)**	0.740 (2.48)*	2.101 (3.77)**	0.170 (0.545)	-0.077 (-0.484)
Average BR Share	.30	.54	.62	.81	.84	.94
NOBS	116	112	118	118	118	108

BR = National Brand, PL = Private Label (t-statistics in parentheses)

** significant at the 1% level. * significant at the 5% level