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Strategic Competition Between Private Labels and National Brands in a Vertically Linked Market

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Abstract

Over the past decades, the rapid emergence of private labels (PL) has created stiff competition for many established manufacturers of national brands (NB). Retailers are using PL products as a competitive weapon against NB. The present study develops and tests different theoretical models of competition under different retailer-manufacturer production arrangements for private labels using the Non-Nested Model Comparison (NNMC) approach and their impact on the pricing strategies of PLs and NBs in the Canadian retail market. The theoretical model shows that a retailer earns the highest profit when it behaves as a leader and makes the least profit when it behaves as a follower; a similar relationship holds for the NB manufacturer under different PL production arrangements. The total industry profit is the highest when the retailer and NB manufacturer behaves in a Bertrand Nash manner. Empirical results of the study show no consistent pattern of competitive interaction under various production arrangements of PL products.

Keywords: Production Arrangement, Leader Follower Game, Bertrand Game, Vertically Linked Market, Private Label, National Brand

JEL Classification: C72, D21, D43, L13

1. Introduction

For the last several decades, manufacturers have been the main producers of branded consumer packaged products at the retail level. However, this leadership position has eroded over time as major grocery retail chains have introduced their own branded products - private label (PL) brands (Gielens et al., 2021; Bauner et al., 2019; Alan et al., 2019; Olbrich et al., 2017). Private label products were viewed as cheap products, but now retailers have started offering better quality products, now the customers consider PL as good as NB substitute products (Gielens et al., 2021). Many studies note that increasing levels of product quality have significantly contributed to the penetration of PLs in many retail product categories

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(Assarzadegan and Hejazi, 2021; Cuneo et al., 2019; Choi, 2017; Martos-Partal et al., 2015). A rise in PL popularity and a focus on its quality, especially healthy product lines (product lines focus on reducing or removing unfavorable ingredients, e.g., fat, sodium, sugar, salt, etc. (Anders and Moeser, 2010)) has intensified brand competition (Yrjola et al., 2020; Volpe, 2010).

Retailers are using PL products as a strategic negotiating tool at the retail level (Cuneo et al., 2019; Kelting et al., 2017; Ru et al., 2015). To date, evidence from the economic literature suggests that retailers may be effectively using PL brand lines to exert market power against many national brand (NB) manufacturers (Bruggemann et al., 2020; Kelting et al., 2017; Meza and Sudhir, 2010; Steiner, 2004). The complex nature of the competitive interactions between PLs and NBs has become a concern (to set the price of NB and PL, to increase profit, share, etc. and to exploit consumers) not only to marketing managers in food industries, but also economists and policymakers responsible for competition policy and fair practices along vertical food marketing channels (Cotterill et al., 2000).

Retailers are using three different production arrangements for PL products (Berges-Sennou, 2006), i.e., own the production facility; outsource PL products from local markets (Kumar and Steenkamp, 2007), and NB manufacturers produce PL products for retailers (Al-Monawer et al., 2021; Cheng et al., 2020; Chen et al., 2010). Economic literature shows that introducing PL products affects horizontal and vertical competition (Lessassy and Jolibert, 2020; Xia and Li, 2015; Berges and Mechemache, 2011). In a vertically linked market, the strategic competition between PLs and NBs is mutually dependent, and the choice of marketing instruments is affected by the rival's competitive behavior under different production arrangements. The production arrangement of the PL brand is critically important to the retailer's and manufacturer's optimal competitive strategy. Therefore, to understand the effect of the marketing mix on the profit of the producer (retailer/NB manufacturer), we need to understand the competitive interaction between a retailer and NB manufacturer under different production arrangements.

The previous literature on competition and production arrangement can be classified into two different streams. The first stream of studies assumes both a particular type of production arrangement of PL and a competitive interaction (leader/follower) between PL and NB manufacturer (Cheng et al., 2020; Ru et al., 2015; Meza and Sudhir, 2010; Karray and Herran, 2009; Wu and Wang, 2005). The

second stream of the literature assumes a particular type of production arrangement of PL products, but they tested various competitive interactions (Cotterill and Putsis, 2001). In reality, the competitive interaction may differ for different product categories under various PL production arrangements. To the best of our knowledge, there is no study that tested various types of competitive interactions under different production arrangements of PL. This work attempts to determine the type of competitive interaction between PL and NB under various PL production arrangements and contribute to our understanding of these ever-evolving markets.

Thus, the purpose of this study is to develop theoretical models that reveal distinct possible vertical arrangements in the context of competing PL and NB at the retail level. We then develop an empirical model framework to explicitly test for different competitive models incorporating alternative vertical production arrangements. The present study contributes significantly to the literature by a) developing theoretical models under various production arrangements of PL brands and shows how the different production arrangements of PL have an impact on both the retailer's and the NB manufacturer's profit; b) testing the nature and extent of pricing competition across different food product categories, between PLs and NBs and under various production arrangements of PL products; c) drawing conclusions regarding how different pricing strategies have an impact on the demand of PLs and NBs in different product categories under different production arrangements.

The remainder of this paper is divided into four sections. Section 2 deals with the model development, Section 3 and 4 are concerned with the data issues and empirical estimation, respectively. Section 5 concludes the finding of the study.

2. Model Development

The present study adopted the new empirical industrial organization (NEIO) approach used by Cotterill and Putsis (2000). Kadiyali et al. (2001) lay out foundations for NEIO and argue that it is based on the development and estimation of structural, strategic, econometric models and firms' competitive behavior. This approach has three essential characteristics: demand specification (linear, logit, etc.), cost specification (constant marginal cost or linear, log-linear specification of cost) and the interaction of competitive behavior (Kadiyali et al., 2001)

The present study is based on the Non-Nested Model Comparison (NNMC) approach to identify the competitive behavior. First, this approach develops

alternative competitive behavior models, such as Bertrand or Stackelberg leader-follower. Then, these strategic models are applied to the dataset, and whichever model best fits the data is considered the most appropriate description of the market (Putsis and Dhar, 1998; Kadiyali et al., 2001).

The present study applied NNMC to understand different competitive behaviors in a vertically linked market and how these behaviors impact equilibrium prices at retail and wholesale levels. The theoretical model assumes that a NB manufacturer and the retailer are using price as a strategic variable. Various scenarios are explained below:

- The NB manufacturer supplies both NB and PL products to the retailer that sells both products to the consumer.
- The NB manufacturer supplies the NB to the retailer, and the retailer outsources a PL product, but the retailer sells both NB and PL products to the consumer.
- The NB manufacturer produces only the NB product and supplies it to the retailer, while the retailer owns the PL production facility. Furthermore, the retailer sells both NB and PL products to the consumer.

2.1. Case 1: NB Manufacturer Produces both NB and PL Product

In this case, the manufacturer produces both products and maximizes profit by setting the wholesale price. The retailer maximizes profit by setting the retail price of the NB and PL.

We specify linear demand function for both NB and PL as

$$Q_i = a_0 - a_1 P_i + a_2 P_j Q_i = a_0 - a_1 P_i + a_2 P_j \quad (1)$$

Where i, j = NB and PL, and i≠j

Where Q_i is the demand for brand i (NB or PL) at price P_i given the price of other brand P_j. We denote$m_{PL} m_{PL}$and$m_{NB} m_{NB}$by the retailer's margin for PL and NB, respectively.

The functional form used in this analysis is linear; using this specification instead of other functional forms (double log) has to do with computation. However, the double log specification complicates the analysis and violates the conditions required to estimate various market structures (Kadiyali et al.,1996). For example, while estimating the leader-follower game, we need to estimate the first-

order condition of the follower and invert it to obtain prices in terms of the leader's price. We then substitute this inverted price condition into the leader's profit maximization condition. With a double log demand specification, this inversion may lead to multiple solutions or a noninvertible solution (Kadiyali et al., 1996). Thus, for tractability, a linear demand specification has been used in this study.

The retailer's objective is to maximize its overall profit. The retailer's profit can be written as

$$\pi_R = m_{PL}Q_{PL} + m_{NB}Q_{NB}\pi_R = m_{PL}Q_{PL} + m_{NB}Q_{NB} \quad (2)$$

Let CP_L and C_{NB} denote the cost of production of PL and NB; W_{PL} and W_{NB} are wholesale prices of PL and NB, respectively. The profit function of the NB manufacturer can be specified as

$$\pi_{NBM} = (W_{NB} - C_{NB})Q_{NB} + (W_{PL} - C_{PL})Q_{PL}\pi_{NBM} = (W_{NB} - C_{NB})Q_{NB} + (W_{PL} - C_{PL})Q_{PL} \quad (3)$$

We derive the first-order conditions assuming a particular competitive behavior to estimate various equilibrium interactions (Stackelberg leader-follower and Bertrand) in a vertically linked market. Bertrand competitive behavior assumes that the competitor does not react to the change in the strategic variable (price) (Kadiyali et al., 2001), while in Stackelberg leader-follower, the leader sets the strategic variable with knowledge of the competitor's reaction in the first stage, and in the second stage, the follower sets the strategic variable (Narasimhan and Wilcox, 1998). The equilibrium values under various equilibrium interactions (Stackelberg leader-follower and Bertrand) are given in Table 1.

Table 1: Equilibrium Values under Various Competitive Interactions When the NB Manufacturer Produces Both NB and PL Products

Equilibrium Values	Manufacturer of NB behaves as a leader and retailer as follower	Retailer behaves as a leader and manufacturer of NB as follower	Bertrand Competition between retailer and manufacturer of NB
Retail Price (P_{PL})	$\frac{1}{4}C_{PL} + \frac{3a_0}{4(a_1 - a_2)}$	$\frac{1}{4}C_{PL} + \frac{3a_0}{4(a_1 - a_2)}$	$\frac{1}{3}C_{PL} + \frac{2a_0}{3(a_1 - a_2)}$
Retail Price (P_{NB})	$\frac{1}{4}C_{NB} + \frac{3a_0}{4(a_1 - a_2)}$	$\frac{1}{4}C_{NB} + \frac{3a_0}{4(a_1 - a_2)}$	$\frac{1}{3}C_{NB} + \frac{2a_0}{3(a_1 - a_2)}$
Wholesale Price (W_{PL})	$\frac{1}{2}C_{PL} + \frac{a_0}{2(a_1 - a_2)}$	$\frac{3}{4}C_{PL} + \frac{a_0}{4(a_1 - a_2)}$	$\frac{2}{3}C_{PL} + \frac{a_0}{3(a_1 - a_2)}$
Wholesale Price (W_{NB})	$\frac{1}{2}C_{NB} + \frac{a_0}{2(a_1 - a_2)}$	$\frac{3}{4}C_{NB} + \frac{a_0}{4(a_1 - a_2)}$	$\frac{2}{3}C_{NB} + \frac{a_0}{3(a_1 - a_2)}$

Equilibrium values show that reducing the NB and PL production costs decrease the retail and wholesale prices, as expected from economic theory. Retail

prices remain the same in both competitive interactions (whether the retailer behaves as a leader or the NB manufacturer behaves as a leader), but it differs for the Bertrand competition. The wholesale price, however, varies under all competitive behaviors. These results show that regardless of who becomes the leader in the market, the leader achieves higher profits.

2.2. Case 2: NB Manufacturer Produces NB Product and Retailer Outsources PL product

In this scenario, the NB manufacturer and PL producer maximize profit by choosing the wholesale price of the NB and PL, respectively. The retailer maximizes profit by choosing the retail price of both the NB and PL products.

The retailer's profit function can be specified as

$$\pi_R = m_{PL}Q_{PL} + m_{NB}Q_{NB}\pi_R = m_{PL}Q_{PL} + m_{NB}Q_{NB} \quad (4)$$

The profit function of the NB and PL manufacturer can be written respectively as

$$\pi_{NBM} = (W_{NB} - C_{NB})Q_{NB} \quad (5)$$

$$\pi_{PLM} = (W_{PL} - C_{PL})Q_{PL} \quad (6)$$

Using a similar approach as used in case 1, equilibrium values under various competitive interactions when the manufacturer produces NB and the retailer outsources the PL product are given in Table 1 in Appendix A. These results show no difference between the retail prices in both leader-follower competitive interactions (see Table 1 in Appendix A), but these prices are different for the Bertrand interaction. Therefore, the signs of equilibrium values are positive given that $a_1 \succ a_2$.

2.3. Case 3: NB Manufacturer Produces NB Product and Retailer Produces PL Product

In this case, the NB manufacturer maximizes its profit by setting the wholesale price of the NB, and the retailer maximizes its profit by setting the retail price of the NB and PL. The theoretical model can be written as

$$Q_i = a_0 - a_1P_i + a_2P_j \quad \text{Where i= NB and PL} \quad (7)$$

$$\pi_R = (P_{PL} - C_{PL})Q_{PL} + m_{NB}Q_{NB} \quad (8)$$

$$\pi_{NBM} = (W_{NB} - C_{NB})Q_{NB} \quad (9)$$

Comparative statistics of the above model are given in Table 2 in Appendix A. Equilibrium values show that the retail price of the NB and PL is identical under both leader-follower behaviors while the wholesale price varies in various competitive interactions.

The cost of producing NBs and PLs positively impacts the retail price of NBs and PLs under all competitive behaviors, which is expected from economic theory. The theoretical model reveals that the leader earns the highest profit when it behaves as a leader. The total industry profit remains the same under both leader-follower behaviors (retailer behaves as a leader or NB manufacturer behaves as a leader). These results are similar to case 1, where the results show that consumers enjoy the lowest price, and the industry earns the highest profit under Bertrand's behavior.

3. Econometric Model Specification

This section briefly describes the derivation of different competitive interactions between PLs and NBs under different production arrangements of PL products. We have discussed only when the NB manufacturer produces both NB and PL products under various competitive interactions. The results of other cases i.e., retailer outsources PL product and retailer owns PL production facility, are given in Appendix B.

3.1. NB Manufacturer Produces both NB and PL Products

Bertrand Behavior between PL and NB

We use the Bertrand and the Stackelberg models to estimate the competitive interaction between NB and PL under various theoretical assumptions. In Bertrand competition, both players (retailer and NB manufacturer) set the price of their own products, assuming that the competitor does not react to this price change (Kadiyali et al., 2001).

$$Q_{PLst} = a_0 + a_1 P_{PLst} + a_2 P_{NBst} + a_3 S_{PLst} + a_4 S_{NBst} + \upsilon_{1st} \quad (10)$$

$$Q_{NBst} = b_0 + b_1 P_{NBst} + b_2 P_{PLst} + b_3 S_{NBst} + b_4 S_{PLst} + \upsilon_{2st} \quad (11)$$

$$P_{PLst} = \left(-\frac{a_2+b_2}{2a_1}\right) P_{NBst} - \frac{(a_0 - b_2 W_{NBst} - a_1 W_{PLst} + a_4 S_{NBst} + a_3 S_{PLst})}{2a_1} + \upsilon_{3st} \quad (12)$$

$$P_{NBst} = \left(-\frac{a_2+b_2}{2b_1}\right) P_{PLst} - \frac{(b_0 - b_1 W_{NBst} - a_2 W_{PLst} + b_3 S_{NBst} + b_4 S_{PLst})}{2b_1} + \upsilon_{4st} \quad (13)$$

$$W_{PLst} = \frac{1}{a_1}(a_1 C_{PLst} + b_2 C_{NBst} - b_2 W_{NBst} - a_0 - a_1 P_{PLst} - a_2 P_{NBst} - a_3 S_{PLst} - a_4 S_{NBst}) + \upsilon_{5st} \quad (14)$$

$$W_{NBst} = \frac{1}{b_1}(b_1 C_{NBst} + a_2 C_{PLst} - a_2 W_{PLst} - b_0 - b_1 P_{NBst} - b_2 P_{PLst} - b_3 S_{NBst} - b_4 S_{PLst}) + \upsilon_{6st} \quad (15)$$

Where Q_{PLst}, Q_{NBst} denote the quantities of PLs and NBs demanded in store s at time t, respectively. S_{PL} and S_{NB} show promotional dummy variables for PL and NB products, respectively. Where $\upsilon_{1st}, \upsilon_{2st}, \upsilon_{3st}, \upsilon_{4st}, \upsilon_{5st}$ and υ_{6st} denote contemporaneously correlated error terms. The present study assumes that these errors are jointly normally distributed, and the equations can be estimated as a simultaneous equation system.

NB manufacturer behaves as a leader and retailer behaves as a follower

In this case, we first need to estimate the first-order conditions of the follower, which is written as

$$P_{PLst} = \left(-\frac{a_2+b_2}{2a_1}\right) P_{NBst} - \frac{1}{2a_1}(a_0 - b_2 W_{NBst} - a_1 W_{PLst} + a_4 S_{NBst} + a_3 S_{PLst}) + \upsilon_{3st} \quad (16)$$

$$P_{NBst} = \left(-\frac{a_2+b_2}{2b_1}\right) P_{PLst} - \frac{1}{2b_1}(b_0 - b_1 W_{NBst} - a_2 W_{PLst} + b_3 S_{NBst} + b_4 S_{PLst}) + \upsilon_{4st} \quad (17)$$

By solving Equation (16) and (17) in terms of W_{NBst} and other exogenous variables, we substitute these expressions into the NB manufacturer maximization problem. The first-order conditions of the NB manufacturer can be written as

$$W_{PLst} = -\frac{a_2+b_2}{2a_1} W_{NBst} + \frac{a_2+b_2}{4a_1} C_{NBst} + \left(\frac{\begin{matrix} a_4 b_2^2 + a_1 a_2 b_3 - 2a_1 b_1 a_4 \\ -a_1 b_2 b_3 + a_2 a_4 b_2 \end{matrix}}{4a_1(a_1 b_1 - a_2 b_2)}\right) S_{NBst} + \left(\frac{\begin{matrix} a_3 b_2^2 - 2a_1 a_3 b_1 + a_1 a_2 b_4 \\ +a_2 a_3 b_2 - a_1 b_2 b_4 \end{matrix}}{4a_1(a_1 b_1 - a_2 b_2)}\right) S_{PLst} + \frac{C_{PLst}}{2} - \frac{\begin{matrix} 2a_0 a_1 b_1 - a_0 b_2^2 - a_1 a_2 b_0 \\ -a_0 a_2 b_2 + a_1 b_0 b_2 \end{matrix}}{4a_1(a_1 b_1 - a_2 b_2)} + \upsilon_{5st} \quad (18)$$

$$W_{NBst} = -\frac{a_2+b_2}{2b_1} W_{PLst} + \frac{a_2+b_2}{4b_1} C_{PLst} + \left(\frac{a_2^2 b_4 - a_2 a_3 b_1 - 2a_1 b_1 b_4 + a_3 b_1 b_2 + a_2 b_2 b_4}{4b_1(a_1 b_1 - a_2 b_2)} \right) S_{PLst} +$$

$$\left(\frac{a_2^2 b_3 - 2a_1 b_1 b_3 - a_2 a_4 b_1 + a_2 b_2 b_3 + a_4 b_1 b_2}{4b_1(a_1 b_1 - a_2 b_2)} \right) S_{NBst} + \frac{C_{NBst}}{2} - \left(\frac{2a_1 b_0 b_1 - a_2^2 b_0 + a_0 a_2 b_1 - a_0 b_1 b_2 - a_2 b_0 b_2}{4b_1(a_1 b_1 - a_2 b_2)} \right) + \upsilon_{6st} \quad (19)$$

To estimate the model properly, we need to estimate Equations (10), (11), (16)-(19) as a system. The endogenous variables in this system are the wholesale price of the NB and PL products, the retail price of the PL and NB products, and the quantity demanded of the NB and PL products, and the remaining variables are all exogenous. Appendix B lists the econometric specifications of the retailer, who behaves as a leader, and the NB manufacturer, who behaves as a follower.

4. Data

For analysis, we chose a product category and product pairings. The regular and healthy PL and NB products were so similar that they could easily be substituted for each other. The matching criterion is based on the fact that products are direct, close substitutes within the same product category and that both products (PL, NB) carry close to identical characteristics as identified from the product description. The analysis in this study is based on a set of proprietary scanner panel data made available through the SIEPR-Giannini Data Center(SIEPR-Giannini Data Center 2012). The data provide retail sales information for 200 UPC product categories for a major North American retail chain with stores in Canada. Aggregate weekly store-level sales data are used from all retailer operational regions. The data include information at the individual UPC level for the price, applicable discounts, sales quantity, and retail gross and net margin.

The present study uses two examples (regular and healthy meat) to see how quality differentiation attributes affect the pricing and competitive promotional interactions between PLs and NBs in the retail categories. In this regard, a) packaged sliced regular meat; and b) packaged sliced healthy (less-salt) meat are used as examples. Table 2 shows the descriptive statistics of NB and PL regular and healthy meat.

Table 2: Descriptive Statistics for NB and PL Regular and Healthy Meat

Particulars	Mean	Std. Dev.	Minimum	Maximum
		Regular Meat		
NB Shelf Price[a]	6.39	0.34	4.57	8.04
NB Promotional Price[b]	5.45	0.91	4.05	8.04
NB Wholesale Price	3.53	0.16	2.33	4.26
PL Shelf Price [a]	3.16	0.18	2.80	3.49
PL Promotional Price [b]	3.06	0.24	2.58	3.49
PL Wholesale Price	1.92	0.06	1.29	1.99
NB Quantity	38.15	32.79	1	247
PL Quantity	9.06	6.26	1	63
		Healthy Meat		
NB Shelf Price [a]	6.39	0.35	4.57	8.04
NB Promotional Price [b]	5.45	0.91	4.43	8.04
NB Wholesale Price	3.54	0.17	1.18	4.28
PL Shelf Price [a]	5.38	0.36	3.68	6.15
PL Promotional Price [b]	4.86	0.74	2.89	5.97
PL Wholesale Price	2.77	0.22	1.30	3.35
NB Quantity	14.99	13.78	1	95
PL Quantity	16.00	16.23	1	209

All prices are in Canadian $ and quantity is measured in number of packages of 500g each. [a] Shelf price: Price printed on the shelf of the product at the retail store. [b] Promotional price: Price accounting for the promotional discounts, coupons and saving through membership cards

A retailer would have three potential production options (i.e., supplies his own PL product, outsources PL, and gets supply both of NB and PL from some manufacturers) to produce the PL product. But we do not know which production arrangement a retailer is using. Therefore, the present study aims to predict the strategic competitive behaviors between the PL and NB under different PL production arrangements. The above models derived are applied to the available data. The model that fits best is considered the best representation of the competitive interaction between PL and NB and the production arrangement of PL.

5. Results and Discussion

The full Information Maximum Likelihood (FIML) method was applied to estimate the demand and price reaction equations as a system. The lowest estimate of Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) was used to select the best-fitted model (Gujarati and Sangeetha, 2007; Greene, 2008).

The study shows leader-follower competitive behavior for both healthy and regular meat. Kadiyali et al. (1996) stated a greater likelihood of leader-follower

behavior when firms interact repeatedly. An interesting question is which firm behaves as a leader and which as a follower. In this regard, the lowest values of AIC and SIC show that the retailer behaves as a leader and the NB manufacturer as a follower for healthy meat and NB manufacturer behaves as a leader and retailer as a follower for regular meat when NB manufacturer produces both NB and PL brand.

Table 3: Values of SIC and AIC for Testing Competitive Games of Regular and Healthy Meat

Particulars	Retailer owns production facility		NB manufacturer produces both NB & PL brand for retailer		Retailer outsources PL products	
	SIC [a]	AIC [b]	SIC [a]	AIC [b]	SIC [a]	AIC [b]
Regular Meat						
NB Manufacturer Behaves as a Leader and retailer behaves as a follower	46993.8	46952.5	41201.9	41159.7	42424.1	42386.1
Retailer behaves as a leader and NB manufacturer as a follower	46291.5	46250.2	42556.1	42522.3	43593.7	43551.5
Retailer and NB manufacturer behaves as a Bertrand manner	46939.7	46898.5	42427.0	42384.8	43867.5	43825.3
Healthy Meat						
NB Manufacturer Behaves as a Leader and retailer behaves as a follower	67997.5	67960.2	58580.7	58546.8	56002.1	55959.8
Retailer behaves as a leader and NB manufacturer as a follower	54448.0	54406.6	52699.5	52657.2	56171.7	56129.5
Retailer and NB manufacturer behaves as a Bertrand manner	53500.2	53458.7	54937.8	54899.7	54451.2	54408.9

[a] Schwarz Information Criterion (SIC). [b]Akaike Information Criterion (AIC)

The demand estimates for these games, for the healthy and the regular meat cases, are given in Table 4. A Wald test is applied to determine how NB and PL promotion dummies[4] jointly affect the demand. The test statistic shows that all the promotional dummy variables have a jointly significant impact on the demand for NBs and PLs regardless of who behaves as leader in the market. The study shows that own price has a negative impact on the PL and NB in both product categories, as expected from economic theory (Kadiyali et al., 1996; Akbay and Jones, 2005; Hirche et al., 2021).

[4]The promotional dummy for NB is equal to 1 when the NB is on promotion and zero otherwise, and PL promotion is equal to 1 when the PL brand is on promotion and zero otherwise.

Table 4: Best Fitted Game of Healthy and Regular Meat

Variable	Healthy Meat NB manufacturer produces both NB & PL brand for retailer Retailer behaves as a leader & NB manufacturer as a follower		Regular Meat NB Manufacturer Behaves as a Leader & retailer behaves as a follower	
	Q_{NB} [a]	Q_{PL} [b]	Q_{NB} [a]	Q_{PL} [b]
Intercept	31.864 (0.606)	76.292 (1.565)	-0.030 (0.033)	4.115 (0.040)
Price NB	-3.991 (0.078)	-1.724 (0.039)	-1.459 (0.003)	0.843 (0.012)
Price PL	1.582 (0.041)	-9.889 (0.212)	0.840 (0.005)	-0.484 (0.001)
Sales Promotion Dummy (NB)	-6.634 (0.149)	1.594 (0.105)	-0.195 (0.004)	-0.354 (0.006)
Sales Promotion Dummy (PL)	0.947 (0.056)	-9.674 (0.209)	-0.123 (0.003)	0.018 (0.004)
Wald Test for all promotional dummies	2784.4**		13154.3**	

** represent statistical significance at 1% level.
Heteroskedasticity consistent standard errors are in parentheses.
[a]Q_{NB} = Quantity of NB, [b] Q_{PL} = Quantity of PL.

The own promotional dummy variables show an inverse relationship between price and quantity demand of regular and healthy meat. It indicates that when the meat is on promotion, the demand will decrease. The reason for this behavior could be that when the product is on promotion, a negative "signal" is sent to consumers, and the latter perceive that the product is of poor quality or maybe close to expire. In the case of regular meat, both promotional dummy variables (own and cross) have negative impacts on the demand of NB. There can be various reasons for such a relationship. Firstly, it may be due to a strong association in the promotional activity between NB and PL, as indicated by the Chi-square statistics. Secondly, the promotional benefits may be available to only those consumers who buy a large quantity of the product; for example, get one free with a pack of four. The consumer may not be willing to buy four units in order to get the benefit of an additional unit. In this case, promotional activity does not have a desirable effect on the demand for the product. Finally, since we do not have detailed information on promotion (promotional expenditure, promotional instruments) and other marketing instruments that are used simultaneously, it is quite possible that the marketing instruments (advertising) used by the rival brand has a bigger effect relative to the product promotion and as a result promotion has a negative impact on the demand of the product.

The own-price elasticity shows that consumers are more responsive to the PL price change as compared to the NB price change in healthy meat (see Table 5). The

reason for this behavior could be that the quality of PL products has increased overtime significantly (Gielens et al., 2021; Hara and Matsubayashi, 2017; Martos-Partal et al., 2015), and it results a tough competition between PL and NB (Gielens et al., 2021; Volpe, 2010; Corstjens and Lal, 2000). Previous literature also shows that price reduction benefits high-quality brands more than low-quality brands (Sivakumar and Raj, 1997; Huang et al., 2010; Yu, 2021).

Table 5: Price Elasticities of Regular and Healthy Meat

Variable	Healthy Meat		Regular Meat	
	NB manufacturer produces both NB & PL brand for retailer			
	Retailer behaves as a leader & NB manufacturer as a follower		NB Manufacturer Behaves as a Leader & retailer behaves as a follower	
	Q_{NB}	Q_{PL}	Q_{NB}	Q_{PL}
P_{NB}	-1.425**	-0.573**	-0.208**	0.507**
P_{PL}	0.503**	-2.93**	0.067**	-0.163**

** represent statistical significance at 1% level.
P_{NB} = Price NB, P_{PL} = Price PL, Q_{NB} = Quantity NB, Q_{PL} = Quantity PL.

The cross-price elasticity of PL has a negative relationship, showing that the PL and NB healthy meat are complementary (as shown in Table 7). Deaton (1987) also reports the complementary relationship between dry fish and fresh fish. Several other studies found similar behavior (Kadiyali et al.,1996; Guo et al., 1999). These estimates indicate that whenever consumers buy PL healthy meat, they also buy NB.

5. Concluding Remarks

The study contributes to develop a theoretical model of PL and NB competition by using NNMC approach under different production arrangements for the retailer's brand (PL). The theoretical model shows that a retailer earns the highest profit when it behaves as a leader and makes the least profit when it behaves as a follower; a similar relationship holds for the NB manufacturer under different production arrangements. The total industry profit is the highest when the retailer and NB manufacturer behaves in a Bertrand Nash manner.

The empirical results show that there is no consistent pattern of competition between PLs and NBs across different food product categories. The pattern of competition also varies depending on how the PL product is produced. These different competitive interactions are consistent with the findings of previous economic studies. The results of the study suggest that researchers should not assume an arbitrary type of competitive interaction while doing the analysis and

making conclusions. If the assumptions regarding the competitive interaction are wrong, it will result in wrong conclusions. The conclusions from these studies should be evaluated considering the assumptions that these studies make regarding the strategic competitive interaction between manufacturer and retailer.

Study results show that there is a leader-follower behavior between brands. Marsden and Whelan (2009) indicate that welfare is maximized when both retailer and NB manufacturer behaves in a Bertrand manner rather than leader-follower relationship. For both brands to behave in a Bertrand manner, the government should play a role by setting competition standards to maximize consumer welfare. The theoretical model also shows that total industry profit is highest when the retailer and the NB manufacturer behave in a Bertrand Nash manner relative to the leader-follower manner. The Bertrand Nash behavior increases competition between brands (PL and NB) which has some tangible benefits for consumers in the form of lower prices, quality improvement of the product, more choice, and better service.

Our study has some limitations. First, it uses scanner data, providing product-level information, but this dataset lacks demographic information. Suppose the focus is to understand better consumer preferences for PL and NB products and how demographic information affects the competitive pricing strategy between PLs and NBs across different product categories. In that case, demographic information should be incorporated in the demand specifications for PLs and NBs. Second, the present study analyzed competition between the PL and NB for two important products, not for the entire product line, while at the retail level, each competing firm supplies a complete product line. Due to the non-availability of data for other products offered by the same producer in its product line, we used only one product from its entire product line. The same holds for the retailer, so the competitive behavior analyzed is based on only one NB and PL product from an entire NB and PL product line. In other words, the conclusions and implications drawn from this study are based on only two products, not on a complete product line. So the generalizability of the results is with the given caution. A similar study can be undertaken for different products and in different regions.

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Appendix A: Mathematical model specification

Table 1: Equilibrium Values under Various Competitive Interactions When the NB Manufacturer produces NB and the Retailer Outsources the PL Product

Equilibrium Values	Manufacturer of NB behaves as a leader and retailer as follower
Retail Price (P_{PL})	$\left(\frac{a_1^2}{4a_1^2-a_2^2}\right)C_{PL}+\left(\frac{a_1a_2}{8a_1^2-2a_2^2}\right)C_{NB}+\frac{a_0(3a_1-2a_2)}{2(a_1-a_2)(2a_1-a_2)}$
Retail Price (P_{NB})	$\left(\frac{a_1^2}{4a_1^2-a_2^2}\right)C_{NB}+\left(\frac{a_1a_2}{8a_1^2-2a_2^2}\right)C_{PL}+\frac{a_0(3a_1-2a_2)}{2(a_1-a_2)(2a_1-a_2)}$
Wholesale Price (W_{PL})	$\left(\frac{1}{4a_1^2-a_2^2}\right)(2a_1^2C_{PL}+a_1a_2C_{NB}+2a_0a_1+a_0a_2)$
Wholesale Price (W_{NB})	$\left(\frac{1}{4a_1^2-a_2^2}\right)(2a_1^2C_{NB}+a_1a_2C_{PL}+2a_0a_1+a_0a_2)$
	Retailer behaves as a leader and manufacturer of NB as follower
Retail Price (P_{PL})	$\left(\frac{a_1^2}{4a_1^2-a_2^2}\right)C_{PL}+\left(\frac{a_1a_2}{8a_1^2-2a_2^2}\right)C_{NB}+\frac{a_0(3a_1-2a_2)}{2(a_1-a_2)(2a_1-a_2)}$
Retail Price (P_{NB})	$\left(\frac{a_1^2}{4a_1^2-a_2^2}\right)C_{NB}+\left(\frac{a_1a_2}{8a_1^2-2a_2^2}\right)C_{PL}+\frac{a_0(3a_1-2a_2)}{2(a_1-a_2)(2a_1-a_2)}$
Wholesale Price (W_{PL})	$\left(\frac{(6a_1^2-a_2^2)}{2(4a_1^2-a_2^2)}\right)C_{PL}+\frac{1}{2}\frac{a_1a_2}{(4a_1^2-a_2^2)}C_{NB}+\frac{a_0}{4a_1-2a_2}$
Wholesale Price (W_{NB})	$\left(\frac{(6a_1^2-a_2^2)}{2(4a_1^2-a_2^2)}\right)C_{NB}+\frac{1}{2}\frac{a_1a_2}{(4a_1^2-a_2^2)}C_{PL}+\frac{a_0}{4a_1-2a_2}$
	Bertrand Competition between the retailer & manufacturer of NB
Retail Price (P_{PL})	$\left(\frac{3a_1^2}{9a_1^2-a_2^2}\right)C_{PL}+\left(\frac{a_1a_2}{9a_1^2-a_2^2}\right)C_{NB}+\frac{a_0(2a_1-a_2)}{(a_1-a_2)(3a_1-a_2)}$
Retail Price (P_{NB})	$\left(\frac{3a_1^2}{9a_1^2-a_2^2}\right)C_{NB}+\left(\frac{a_1a_2}{9a_1^2-a_2^2}\right)C_{PL}+\frac{a_0(2a_1-a_2)}{(a_1-a_2)(3a_1-a_2)}$
Wholesale Price (W_{PL})	$\left(\frac{6a_1^2}{9a_1^2-a_2^2}\right)C_{PL}+\left(\frac{2a_1a_2}{9a_1^2-a_2^2}\right)C_{NB}+\frac{a_0}{(3a_1-a_2)}$
Wholesale Price (W_{NB})	$\left(\frac{6a_1^2}{9a_1^2-a_2^2}\right)C_{NB}+\left(\frac{2a_1a_2}{9a_1^2-a_2^2}\right)C_{PL}+\frac{a_0}{(3a_1-a_2)}$

Table 2: Equilibrium Values under Various Competitive Interactions When the NB Manufacturer Produces NB and the Retailer Owns the PL Production Facility

Particulars	Manufacturer of NB behaves as a leader and retailer as follower	Retailer behaves as a leader and manufacturer of NB as follower
Retail Price (P_{PL})	$\frac{1}{2}C_{PL}+\frac{a_0}{2(a_1-a_2)}$	$\frac{1}{2}C_{PL}+\frac{a_0}{2(a_1-a_2)}$
Retail Price (P_{NB})	$\frac{1}{4}C_{NB}+\frac{a_2}{4a_1}C_{PL}+\frac{a_0(3a_1-a_2)}{4a_1(a_1-a_2)}$	$\frac{1}{4}C_{NB}+\frac{a_2}{4a_1}C_{PL}+\frac{a_0(3a_1-a_2)}{4a_1(a_1-a_2)}$
Wholesale Price (W_{NB})	$\frac{1}{2}C_{NB}+\frac{a_2}{2a_1}C_{PL}+\frac{a_0}{2a_1}$	$\frac{3}{4}C_{NB}+\frac{a_2}{4a_1}C_{PL}+\frac{a_0}{4a_1}$
	Bertrand Competition between retailer & manufacturer of NB	
Retail Price (P_{PL})	$\frac{1}{2}C_{PL}+\frac{a_0}{2(a_1-a_2)}$	
Retail Price (P_{NB})	$\frac{1}{3}C_{NB}+\frac{a_2}{6a_1}C_{PL}+\frac{a_0(4a_1-a_2)}{6a_1(a_1-a_2)}$	
Wholesale Price (W_{NB})	$\frac{2}{3}C_{NB}+\frac{a_2}{3a_1}C_{PL}+\frac{a_0}{3a_1}$	

Appendix B: Econometric Model Specifications

Case 1 Manufacturer of NB produces both NB and PL products

1.1. Retailer behaves as a leader and manufacturer of NB behaves as a follower

$$Q_{PLst} = a_0 + a_1 P_{PLst} + a_2 P_{NBst} + a_3 S_{PLst} + a_4 S_{NBst} + \upsilon_{1st}$$

$$Q_{NBst} = b_0 + b_1 P_{NBst} + b_2 P_{PLst} + b_3 S_{NBst} + b_4 S_{PLst} + \upsilon_{2st}$$

$$W_{PLst} = \frac{1}{a_1}\left(a_1 C_{PLst} + b_2 C_{NBst} - b_2 W_{NBst} - a_0 - a_1 P_{PLst} - a_2 P_{NBst} - a_3 S_{PLst} - a_4 S_{NBst}\right) + \upsilon_{3st}$$

$$W_{NBst} = \frac{1}{b_1}(b_1 C_{NBst} + a_2 C_{PLst} - a_2 W_{PLst} - b_0 - b_1 P_{NBst} - b_2 P_{PLst} - b_3 S_{NBst} - b_4 S_{PLst}) + \upsilon_{4st}$$

$$P_{PLst} = \frac{1}{4} C_{PLst} - \frac{a_2 + b_2}{2a_1} P_{NBst} + \frac{b_2}{4a_1} C_{NBst} + \left(\frac{a_4 b_2^2 + a_1 a_2 b_3 - 3a_1 b_1 a_4 - a_1 b_2 b_3 + 2a_2 a_4 b_2}{4a_1 (a_1 b_1 - a_2 b_2)} \right) S_{NBst}$$

$$+ \left(\frac{a_3 b_2^2 - 3a_1 a_3 b_1 + a_1 a_2 b_4 + 2a_2 a_3 b_2 - a_1 b_2 b_4}{4a_1 (a_1 b_1 - a_2 b_2)} \right) S_{PLst} - \left(\frac{3a_0 a_1 b_1 - a_0 b_2^2 - a_1 a_2 b_0 - 2a_0 a_2 b_2 + a_1 b_0 b_2}{4a_1 (a_1 b_1 - a_2 b_2)} \right) + \upsilon_{5st}$$

$$P_{NBst} = \frac{1}{4} C_{NBst} - \frac{a_2 + b_2}{2b_1} P_{PLst} + \frac{a_2}{4b_1} C_{PLst} + \left(\frac{a_2^2 b_4 - a_2 a_3 b_1 - 3a_1 b_1 b_4 + a_3 b_1 b_2 + 2a_2 b_2 b_4}{4b_1 (a_1 b_1 - a_2 b_2)} \right) S_{PLst}$$

$$+\left(\frac{\begin{matrix}a_2^2b_3-3a_1b_1b_3-a_2a_4b_1\\+2a_2b_2b_3+b_1a_4b_2\end{matrix}}{4b_1(a_1b_1-a_2b_2)}\right)S_{PLst}-\left(\frac{\begin{matrix}3a_1b_0b_1-a_2^2b_0+a_0a_2b_1\\-a_0b_1b_2-2a_2b_0b_2\end{matrix}}{4b_1(a_1b_1-a_2b_2)}\right)+\upsilon_{6st}$$

Case 2 Retailer outsources PL products

2.1. Bertrand Competition

$$Q_{PLst}=a_0+a_1P_{PLst}+a_2P_{NBst}+a_3S_{PLst}+a_4S_{NBst}+\upsilon_{1st}$$

$$Q_{NBst}=b_0+b_1P_{NBst}+b_2P_{PLst}+b_3S_{NBst}+b_4S_{PLst}+\upsilon_{2st}$$

$$P_{PLst}=\left(-\frac{a_2+b_2}{2a_1}\right)P_{NBst}-\frac{1}{2a_1}(a_0-b_2W_{NBst}-a_1W_{PLst}+a_4S_{NBst}+a_3S_{PLst})+\upsilon_{3st}$$

$$P_{NBst}=\left(-\frac{a_2+b_2}{2b_1}\right)P_{PLst}-\frac{1}{2b_1}(b_0-b_1W_{NBst}-a_2W_{PLst}+b_3S_{NBst}+b_4S_{PLst})+\upsilon_{4st}$$

$$W_{PLst}=\frac{1}{a_1}(a_1C_{PLst}-a_0-a_1P_{PLst}-a_2P_{NBst}-a_3S_{PLst}-a_4S_{NBst})+\upsilon_{5st}$$

$$W_{NBst}=\frac{1}{b_1}(b_1C_{NBst}-b_0-b_1P_{NBst}-b_2P_{PLst}-b_3S_{NBst}-b_4S_{PLst})+\upsilon_{6st}$$

2.2. Manufacturer of NB and PL behave as a leader and retailer behaves as a follower

$$Q_{PLst}=a_0+a_1P_{PLst}+a_2P_{NBst}+a_3S_{PLst}+a_4S_{NBst}+\upsilon_{1st}$$

$$Q_{NBst}=b_0+b_1P_{NBst}+b_2P_{PLst}+b_3S_{NBst}+b_4S_{PLst}+\upsilon_{2st}$$

$$P_{PLst}=\left(-\frac{a_2+b_2}{2a_1}\right)P_{NBst}-\frac{1}{2a_1}\left(a_0-b_2W_{NBst}-a_1W_{PLst}+a_4S_{NBst}+a_3S_{PLst}\right)+\upsilon_{3st}$$

$$P_{NBst} = \left(-\frac{a_2 + b_2}{2b_1}\right) P_{PLst} - \frac{1}{2b_1}(b_0 - b_1 W_{NBst} - a_2 W_{PLst} + b_3 S_{NBst} + b_4 S_{PLst}) + v_{4st}$$

$$W_{PLst} = \left(-\frac{a_2 + b_2}{4a_1}\right) W_{NBst} + \left(\frac{\begin{matrix}a_3 b_2^2 - 2a_1 a_3 b_1 + a_1 a_2 b_4 \\ +a_2 a_3 b_2 - a_1 b_2 b_4\end{matrix}}{4a_1(a_1 b_1 - a_2 b_2)}\right) S_{PLst} + \left(\frac{\begin{matrix}a_4 b_2^2 + a_1 a_2 b_3 - 2a_1 b_1 a_4 \\ -a_1 b_2 b_3 + a_2 a_4 b_2\end{matrix}}{4a_1(a_1 b_1 - a_2 b_2)}\right) S_{NBst} + \frac{1}{2} C_{PLst} - \left(\frac{\begin{matrix}2a_0 a_1 b_1 - a_0 b_2^2 - a_1 a_2 b_0 \\ -a_0 a_2 b_2 + a_1 b_0 b_2\end{matrix}}{4a_1(a_1 b_1 - a_2 b_2)}\right) + v_{5st}$$

$$W_{NBst} = \left(-\frac{a_2 + b_2}{4b_1}\right) W_{PLst} + \left(\frac{\begin{matrix}a_2^2 b_4 - a_2 a_3 b_1 - 2a_1 b_1 b_4 \\ +a_3 b_1 b_2 + a_2 b_2 b_4\end{matrix}}{4b_1(a_1 b_1 - a_2 b_2)}\right) S_{PLst} + \left(\frac{\begin{matrix}a_2^2 b_3 - 2a_1 b_1 b_3 - a_2 a_4 b_1 \\ +a_2 b_2 b_3 + a_4 b_1 b_4\end{matrix}}{4b_1(a_1 b_1 - a_2 b_2)}\right) S_{NBst} + \frac{1}{2} C_{NBst} + \left(\frac{\begin{matrix}a_2^2 b_0 - a_0 a_2 b_1 - 2a_1 b_0 b_1 \\ +a_0 b_1 b_2 + a_2 b_0 b_2\end{matrix}}{4b_1(a_1 b_1 - a_2 b_2)}\right) + v_{6st}$$

2.3. Retailer behaves as a leader and manufacturer of NB behaves as a follower

$$Q_{PLst} = a_0 + a_1 P_{PLst} + a_2 P_{NBst} + a_3 S_{PLst} + a_4 S_{NBst} + v_{1st}$$

$$Q_{NBst} = b_0 + b_1 P_{NBst} + b_2 P_{PLst} + b_3 S_{NBst} + b_4 S_{PLst} + v_{2st}$$

$$W_{PLst} = \frac{1}{a_1}(a_1 C_{PLst} - a_0 - a_1 P_{PLst} - a_2 P_{NBst} - a_3 S_{PLst} - a_4 S_{NBst}) + v_{3st}$$

$$W_{NBst} = \frac{1}{b_1}(b_1 C_{NBst} - b_0 - b_1 P_{NBst} - b_2 P_{PLst} - b_3 S_{NBst} - b_4 S_{PLst}) + \upsilon_{4st}$$

$$P_{PLst} = \frac{b_1 b_2}{2b_2^2 + 4a_1 b_1} C_{NBts} - \left(\frac{3a_2 b_1 + 3b_1 b_2}{2b_2^2 + 4a_1 b_1}\right) P_{NBst} - \left(\frac{3b_1 a_4 + 2b_2 b_3}{2b_2^2 + 4a_1 b_1}\right) S_{NBts}$$
$$- \left(\frac{3a_3 b_1 + 2b_2 b_4}{2b_2^2 + 4a_1 b_1}\right) S_{PLst} + \frac{a_1 b_1}{2b_2^2 + 4a_1 b_1} C_{PLst} - \frac{3a_0 b_1 + 2b_0 b_2}{2b_2^2 + 4a_1 b_1} + \upsilon_{5st}$$

$$P_{NBst} = \frac{a_1 b_1}{2a_2^2 + 4a_1 b_1} C_{NBts} - \left(\frac{3a_1 a_2 + 3a_1 b_2}{2a_2^2 + 4a_1 b_1}\right) P_{PLst}$$
$$- \left(\frac{3b_3 a_1 + 2a_2 a_4}{2a_2^2 + 4a_1 b_1}\right) S_{NBts}$$
$$- \left(\frac{2a_2 a_3 + 3a_1 b_4}{2a_2^2 + 4a_1 b_1}\right) S_{PLst} + \frac{a_1 a_2}{2a_2^2 + 4a_1 b_1} C_{PLst} - \frac{2a_0 a_2 + 3a_1 b_0}{2a_2^2 + 4a_1 b_1} + \upsilon_{6st}$$

Case 3 Retailer owns the production facility

3.1. Bertrand Competition

$$Q_{PLst} = a_0 + a_1 P_{PLst} + a_2 P_{NBst} + a_3 S_{PLst} + a_4 S_{NBst} + \upsilon_{1st}$$

$$Q_{NBst} = b_0 + b_1 P_{NBst} + b_2 P_{PLst} + b_3 S_{NBst} + b_4 S_{PLst} + \upsilon_{2st}$$

$$P_{PLst} = \left(-\frac{(a_2 + b_2)}{2a_1}\right) P_{NBst} - \frac{1}{2a_1}(a_0 - b_2 W_{NBst} - a_1 C_{PLst} + a_4 S_{NBst} + a_3 S_{PLst}) + \upsilon_{3st}$$

$$P_{NBst} = \left(-\frac{(a_2 + b_2)}{2b_1}\right) P_{PLst} - \frac{1}{2b_1}(b_0 - b_1 W_{NBst} - a_2 C_{PLst} + b_3 S_{NBst} + b_4 S_{PLst}) + \upsilon_{4st}$$

$$W_{NBst} = \frac{1}{b_1}(b_1 C_{NBst} - b_0 - b_1 P_{NBst} - b_2 P_{PLst} - b_3 S_{NBst} - b_4 S_{PLst}) + \upsilon_{5st}$$

3.2. Retailer's brand (PL) behaves as a leader and manufacturer's brand as a follower

$$Q_{PLst} = a_0 + a_1 P_{PLst} + a_2 P_{NBst} + a_3 S_{PLst} + a_4 S_{NBst} + \upsilon_{1st}$$

$$Q_{NBst} = b_0 + b_1 P_{NBst} + b_2 P_{PLst} + b_3 S_{NBst} + b_4 S_{PLst} + \upsilon_{2st}$$

$$P_{PLst} = \left(-\frac{a_2 b_1 + 3 b_1 b_2}{2 b_2^2 + 2 a_1 b_1}\right) P_{NBst} - \left(\frac{b_1 a_4 + 2b\ {}_2 b_3}{2 b_2^2 + 2 a_1 b_1}\right) S_{NBst} - \left(\frac{a_3 b_1 + 2 b_2 b_4}{2 b_2^2 + 2 a_1 b_1}\right) S_{PLst} + \frac{a_1 b_1}{2 b_2^2 + 2 a_1 b_1} C_{PLst} + \frac{b_1 b_2}{2 b_2^2 + 2 a_1 b_1} C_{NBst} - \frac{a_0 b_1 + 2 b_0 b_2}{2 b_2^2 + 2 a_1 b_1} + \upsilon_{3st}$$

$$P_{NBst} = \left(-\frac{(a_2 + 3 b_2)}{4 b_1}\right) P_{PLst} + \frac{a_2}{4 b_1} C_{PLst} - \frac{3 b_4}{4 b_1} S_{PLst} - \frac{3 b_3}{4 b_1} S_{NBst} + \frac{1}{4} C_{NBst} - \frac{3 b_0}{4 b_1} + \upsilon_{4st}$$

$$W_{NBst} = \frac{1}{b_1}(b_1 C_{NBst} - b_0 - b_1 P_{NBst} - b_2 P_{PLst} - b_3 S_{NBst} - b_4 S_{PLst}) + \upsilon_{5st}$$

3.3. NB manufacturer behaves as a leader and retailer's brand as a follower

$$Q_{PLst} = a_0 + a_1 P_{PLst} + a_2 P_{NBst} + a_3 S_{PLst} + a_4 S_{NBst} + \upsilon_{1st}$$

$$Q_{NBst} = b_0 + b_1 P_{NBst} + b_2 P_{PLst} + b_3 S_{NBst} + b_4 S_{PLst} + \upsilon_{2st}$$

$$P_{PLst} = \left(-\frac{(a_2 + b_2)}{2 a_1}\right) P_{NBst} - \frac{1}{2 a_1}(a_0 - b_2 W_{NBst} - a_1 C_{PLst} + a_4 S_{NBst} + a_3 S_{PLst}) + \upsilon_{3st}$$

$$P_{NBst} = \left(-\frac{(a_2 + b_2)}{2 b_1}\right) P_{PLst} - \frac{1}{2 b_1}(b_0 - b_1 W_{NBst} - a_2 C_{PLst} + b_3 S_{NBst} + b_4 S_{PLst}) + \upsilon_{4st}$$

$$W_{NBst} = \frac{1}{2} C_{NBst} - \frac{(a_2 + b_2)}{4 b_1} C_{PLst} - \left(\frac{a_2 a_3 b_1 - a_2^2 b_4 + 2 a_1 b_1 b_4 - a_3 b_1 b_2 - a_2 b_2 b_4}{4 b_1 (a_1 b_1 - a_2 b_2)}\right) S_{PLst}$$

$$-\left(\frac{\begin{matrix}2a_1b_1b_3 - a_2^2b_3 + a_2b_1a_4\\ -a_2b_2b_3 - b_1a_4b_2\end{matrix}}{4b_1(a_1b_1 - a_2b_2)}\right)S_{NBst} - \left(\frac{\begin{matrix}a_0a_2b_1 - a_2^2b_0 + 2a_1b_0b_1\\ -a_0b_1b_2 - a_2b_0b_2\end{matrix}}{4b_1(a_1b_1 - a_2b_2)}\right) + v_{5st}$$