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Private Label Introduction: Does it Benefit the Supply Chain?[1]

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Abstract

Private labels, also called store brands or distributor brands, have changed the retail industry during the last three decades. Consumer data shows strong growth of private label market share, and in countries like Germany or Spain, the penetration of private labels is above 30% of total retail sales. This paper analyzes the channel dynamics in a category where a private label is introduced. We focus on the impact of private labels on retail and wholesale equilibrium prices, as well as on the profits of each firm of the supply chain. While private label introduction helps the retailer reduce manufacturer brand's prices, we find that it does not always improve the total profits of the supply chain. Generally, the supply chain benefits from this introduction only when cross-elasticities are small, i.e., competitive interactions are weak. With our model, we formulate the general conditions under which retailers should consider introducing private labels.

Keywords: Private label, non-cooperative game theory, supply chain efficiency.

1 Introduction

Private labels are the products that are specific to a retail chain and cannot be bought at competing retailers. They are controlled by the retailer who has exclusive rights on them. They are manufactured by the retail chain or a third-party manufacturer. This third-party manufacturer can specialize in private labels, e.g., Cott of Canada in soft drinks; or produce both manufacturer brands and private labels, e.g., Friesland-Campina of the Netherlands in dairy products. Private labels in fast-moving consumer goods (FMCG) have been around for more than half a century (the German hard discounter Aldi has been selling them since 1948). They were originally associated with low price and poor quality, but by the first decade of the 21st century this image has changed completely: today some retail chains sell private label products that are of equal or superior quality than well established brands and premium brands (e.g., Tesco's Finest). This leads to new and more complex competitive dynamics in retail.

The current economic environment has a detrimental effect on the bottom line of retailers - with the exception of discounters [24]. It has induced several retailers to increase the share

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of private label products in their stores [25, 26, 27]. This is but the latest development in a trend towards an increased share of private label in retail. Reports published by ACNielsen, GfK and other market researchers indicate that private label brands outpaced manufacturer brands (commonly known as brands) in more than half of the markets measured [1]. Total sales of private label grocery products in Europe reached $250Bn in 2005 and the growth of private label sales has been stronger than that of manufacturer brands. Due to all of the above, companies producing manufacturer brands now see private labels as one of their most important challenges: "a bigger problem for the global brands is that retailers are turning over more and more shelf space to their own labels." [2]

Private labels allow retailers to offer products in market niches not served by manufacturer brands and are a tool to generate shopper loyalty. They offer the additional benefit of very low marketing and sales costs (e.g., no costly advertising campaigns or end-of-aisle displays), resulting in a lower cost structure. Some private label products have a higher percentage profit margin (but lower absolute margin), while others offer higher absolute profit margin than manufacturer brands to the retailer.

Aware of these and other benefits, retailers are increasingly using private labels to gain leverage in their relationships with manufacturer brands. The strategic interaction of private labels with manufacturer brands has been studied in the academic literature: the general conclusion from the research is that private labels reduce *double marginalization* in the prices of the branded product. Double marginalization is a prevalent phenomenon in supply chain management and has been studied since Spengler [22]. Essentially, it consists in having both the manufacturer and the retailer capturing a profit margin independently, without coordination, which results in higher prices than what would be optimal for the entire supply chain. When introducing a private label, the retailer de facto reduces the retail price of one of the products in the category, which forces the manufacturer to respond by reducing its wholesale prices. This in turn translates in a lower retail price of the manufacturer brand, which reduces the double marginalization effect.

Interestingly, while most of the existing papers imply that this mitigation of double marginalization is beneficial for the supply chain, it turns out that this might not always be so. In this paper, we explore the effect of private label introduction on supply chain efficiency. This is novel to the literature, that has mostly examined the impact of private labels on retailers and manufacturers, separately. We propose a simple model for the analysis of the competitive dynamics between one retailer and several manufacturers when one of the manufacturer brands is replaced by a private label. We model demand of each product (manufacturer brand or private label) as a function of its price and the price gap with other products, and analyze the equilibrium prices resulting in such system. We find that the retailer is always better off introducing the private label, manufacturers always worse off. Surprisingly, the total supply chain profit may be lower with the private label, specifically when the substitution between products is high. We show that our findings, obtained under a parsimonious model, are robust to the modeling assumptions on the demand. We can thus use the insights of our model to build recommendations on the use of private labels in retail chains.

The rest of the paper is organized as follows. We review the related literature in §2. We then present our basic game-theoretic model and discuss the impact of a private label in §3. §4 shows how to apply our model to more general assumptions on customer behavior (demand) and the competitive setting (number of manufacturers in the category). We conclude the paper with recommendations in §5.

2 Literature Review

There is a vast literature on private labels, mostly in the marketing and operations management literature. Kumar and Steenkamp [12] provide a broad overview of the problems in the field. Most of the research focuses on understanding the impact of private label introductions on prices and market shares. It includes analytical models and empirical work. Jeuland and Shugan [8] address the coordination problem in differentiated channels (supply chains). McGuire and Staelin [15] present a model to analyze Nash equilibria in duopoly structures, where each manufacturer distributes its goods through a single and exclusive retailer. They introduce a parameter for substitutability for the two end-products into the analysis and show that product substitutability does influence the equilibrium distribution structure. Shugan and Jeuland [20] build on the model presented in McGuire and Staelin [15] and present a basic framework for analyzing competitive pricing behavior in distribution systems. The authors model two manufacturers that sell through two different outlets. They analyze several channel configurations and present the corresponding equilibria functions (vertical channel competing with vertical channel; vertical channel competing with manufacturer Stackelberg, etc.). They develop a set of tools to analyze channels of distribution and show that vertical systems (or coordinated systems) may be more enduring than other channel arrangements. Building on Shugan and Jeuland [20], Choi [4] presents a model that analyzes the price dynamics of two competing manufacturer brand manufacturers that sell through a common retailer. He analyzes the dynamics of three different non-cooperative games (retailer Stackelberg, manufacturer Stackelberg and vertical Nash) both for linear and non-linear price-dependent demand. His findings are supported by empirical evidence, with one exception: his model predicts increasing prices and profits as products become less differentiated. Raju et al. [18] provide an exhaustive analysis of what makes a product category more conducive for private label introduction. They identify that higher price competition between national brands and store brand as a key driver of store brand introduction. Lee and Staelin [11] analyze vertical strategic interaction between channel players and its effect on key channel pricing strategies. In their analysis, they employ several families of demand functions and emphasize the need to be aware of the implications of assuming special form of the demand functions. They find situations in which a channel member can be better off by not using foresight of the other channel member's reaction if the latter also has the ability and motivation to use foresight in making the pricing decision. Trivedi [23] analyzes the effect of different channel structures (integrated, decentralized and full distribution channel) on profits and prices. In her analysis, she assumes a symmetric channel structure, i.e., both channels are either integrated, decentralized or full, but points out that future research should consider asymmetric structures. Kurtuluş and Toktay [13] analyze category management practices, which can be thought of as a vertical integration between the retailer and one manufacturer, and hence is similar to the use of private labels. While these papers focus on the substitution aspect (both in products and stores) of competition and its impact on prices and most use the basic linear duopoly demand function that captures product differentiation, we use a similar model to analyze a different type of relationship, i.e., the dynamics of a multi-brand retailer with respect to independent manufacturers and one captive private label producer. We also extend these models to more general demand structures and any number of players.

Another stream of literature deals with channel dynamics using Hotelling models, that are used to model quality differentiation between products. Narasimhan and Wilcox [16] analyze a retailer's strategic use of private label as a means of obtaining better terms of trade from national brand manufacturers. More recently, Chen et al. [5] study the effect that developments costs and differentiated marginal costs for retailers have on channel dynamics. Groznik and Heese [6] analyze price commitment as a way for manufacturers to prevent store brand introduction. They also consider store brand introduction dynamics with retail competition in [7]. In our model we do not consider quality differences between products, and hence a Hotelling model is not necessary (without quality differentiation, a Hotelling model induces a Bertrand equilibrium where all market share goes to one firm, most likely the private label manufacturer; this is in stark contrast with reality).

The focus of our analysis, in contrast with earlier papers, is to understand the impact of private label introduction on supply chain efficiency, which is a missing element in the literature. In this respect, our paper is close to the research on supply chain coordination. Spengler [22] discusses how decentralized pricing decisions lead to loss of supply chain profits, the so-called double marginalization. Lariviere and Porteus [10] and Cachon and Lariviere [3] show that double marginalization prevails even when retail prices are exogenous (in the sense that the total quantity sold on the market is smaller than the optimal quantity) under demand uncertainty. Perakis and Roels [17] provide bounds on the resulting inefficiency. While most of these papers focus on a single retailer single manufacturer setting, Martínez-de-Albéniz and Roels [14] analyze double marginalization with multiple retailers and a shared, limited shelf space.

3 Basic Model and Results

In this section, we present a basic model with one retailer and two products (supplied either by two manufacturer brands or by one manufacturer brand and one private label), and linear demand functions. We relax these assumptions in §4 to show the robustness of our findings.

3.1 Setting

Consider a retailer that sells two products in the same category. These two products are initially supplied by two independent manufacturers. The retailer's objective is to evaluate whether to replace one manufacturer brand by a private label that it directly controls. This is one of the typical features of private labels: retailers indeed have full control over product design, manufacturing, logistics and merchandizing decisions. Usually, private label products are produced by brand manufacturers, private label manufacturers or by vertically integrated retailers. A brand manufacturer can decide to manufacture private label (e.g., Friesland-Campina, a Dutch company, is organized in manufacturer brand and private label divisions) because it is being forced by the retailer to do so, in order to improve its economies of scale, or to avoid its competitor from producing private label. In the latter case it would be willing to supply the private label at the competitor's cost or at variable cost, whichever is higher (assuming there is no price dumping). Pure private label manufacturers (e.g., Cott Corporation, Canada) supply to one or several retailers, each with his own private label. Finally, a manufacturer can be vertically integrated with the retailer and produce its private label (one example would be Aldi Nord in Germany, see Mitchell and Sachon [19]) or cooperate in a way that avoids the problem of double marginalization (e.g., Mercadona and its "interproveedores" in Spain). In both instances it is the purchasing power of the retailer that drives this cooperation. In what follows, we will assume the latter to be the case.

The basic model thus includes two scenarios.

1. In the first scenario, denoted M+M, there are three different parties in the supply chain, manufacturer 1 (M1), manufacturer 2 (M2) and retailer (R). M1 and M2 produce their products at costs c_1, c_2 and sell them to R at wholesale prices equal to w_1, w_2, respectively. R then chooses retail prices p_1, p_2 for them. Of course, since they are independent, each member tries to maximize its own profit without cooperating with any of the other channel members.
2. In the second scenario, denoted M+PL, there are only two different entities, M1 and the *coalition* of M2 and R. Indeed, if the retailer introduces a private label to replace the M2's product, the transfer (wholesale) price of this product is now the true cost of the item, i.e., $w_2 = c_2$. As a result, the retailer now maximizes the joint profit of M2 and R. In fact when setting $w_i = c_i$, the private label manufacturer makes zero profit from selling the item, and is instead compensated through a flat payment to cover its fixed costs plus a negotiated fixed margin, usually small.

Figure 1 illustrates the two scenarios.

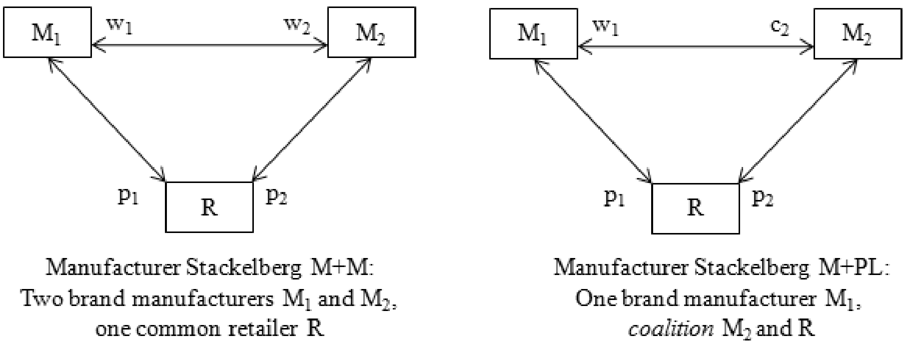

Figure 1: Two competing manufacturer brands (left, Choi [4]), manufacturer brand vs. private label (right).

We analyze both scenarios using a non-cooperative game à la Stackelberg, where the manufacturers are leaders or first-movers, and the retailer is follower or second-mover. One could alternatively consider a different sequence of events and the qualitative nature of the results would not change.

The analysis of the first scenario M+M is similar to the manufacturer-Stackelberg model in Choi [4]. In this setting, we capture the dynamics of product categories with two strong brands, often the category leaders (e.g., Coca-Cola and Pepsi Cola in the soda industry). In this game each brand manufacturer chooses its wholesale pricing w_i based on the retailer's response function and conditioned on the observed wholesale price of the competitor's brand. The retailer chooses the price of each product, p_1, p_2, so that it maximizes the total profit obtained from selling both types of products, given their respective wholesale prices. Manufacturers (strong brands) control the market and know each other's wholesale prices. In this respect, we characterize the Nash equilibrium of the game, where each manufacturer has no incentive to unilaterally change its price given its competitor's price.

The analysis of the second scenario is M+PL is novel. The dynamics are similar as in the previous case: the independent manufacturer now sets its price w_1 taking into account that the retailer will set p_1, p_2 higher or lower depending on w_1. In comparison, the game in this scenario is simply a sequential game where first the brand manufacturer sets its wholesale price and then the retailer sets retail prices for both products.

3.2 Demand Model

The analysis of the competitive dynamics relies on how customer behavior is modeled. While most of the product line design literature uses a Hotelling model to split the pool of customers into the ones that prefer product 1 and the ones that prefer 2, this modeling approach is not appropriate in our setting if we focus on products that are not differentiated in quality, see Kumar and Steenkamp [12]. Indeed, when both products have the same quality, the Hotelling model dictates that consumers, regardless of their valuation of quality, will all choose one product or the other. This translates into having a demand function that is discontinuous on the price of the item (essentially, demand is zero for the product with higher retail price), which results in Bertrand competition, i.e., manufacturers setting $w_i = c_i$ and making no profit.

Since this approach does not match the empirical studies in retail, we choose to model demand as a standard price-dependent function. Specifically, we assume that the retail sales of product i, denoted q_i, depends both on its price p_i, and its competitor's price p_{-i}. For simplicity, we use a linear demand function, although we explore more general demand functions later. While this might present technical problems (demand might become negative for some values of p_i, p_{-i}), it is widely used in the literature, e.g., Choi [4], Raju [18] or Kurtuluş and Toktay [13], and can be thought of the linearized version around equilibrium of any demand function. As a result, we choose the parameters of the demand function so that all the quantities sold are positive (i.e., α, defined below, is high enough).

We assume that for $i = 1, 2$,

$$q_i(p_1, p_2) = \alpha - \beta p_i - \theta(p_i - p_{-i}) \tag{1}$$

The demand function depends on three parameters. α is the potential sales that each product i can obtain when both products are distributed for free, and represents the scale of the market. β captures the price elasticity of demand with respect to one's price, keeping the *price gap* $p_i - p_{-i}$ constant. We set $\beta > 0$ in order to guarantee that when prices of both manufacturers increase in the same amount, demand decreases. The cross-price elasticity $\theta > 0$ represents the substitutability between products: for the same price gap $p_i - p_{-i} > 0$ (< 0), the additional demand that i can lose (gain) increases with higher θ. It is worth pointing out that setting $\theta > 0$ implies that the products are *substitutes*, which is exactly the type of strategic interaction that we want to model, since they are in the same category. Also, we set the cross-elasticity between both products to be identical, so that in a way the number of customers "leaving" M1 for M2, $\theta(p_1 - p_2)$ is equal to the number of customers switching to M2 from M1, $-\theta(p_2 - p_1)$. In contrast, the standard price elasticity with respect to p_i is $\beta + \theta$. Note that in order to guarantee that the quantities are always positive, α should be large compared to β, θ. Finally, observe that these parameters are symmetric, which simplifies the exposition. It is possible to consider α and β different across products without affecting the results, see §4.1.

Having defined the demand function, we can now define the manufacturers' profit function

$$\Pi_{M1} = (w_1 - c_1)q_1 \text{ and } \Pi_{M2} = (w_2 - c_2)q_2 \tag{2}$$

and the retailer's profit function

$$\Pi_R = (p_1 - w_1)q_1 + (p_2 - w_2)q_2 \tag{3}$$

One can observe that these profit functions are quadratic concave, which implies that it is possible to calculate analytically (1) the retailer's best-response strategy $p_1^{BR}(w_1, w_2), p_2^{BR}(w_1, w_2)$ to any w_1, w_2; (2) the best-response function w_i^{BR} to the competitor's wholesale price w_{-i}, for each manufacturer M1, M2; and (3) the equilibrium wholesale prices w_1^{eq} and w_2^{eq}, retail prices $p_1^{eq} = p_1^{BR}(w_1^{eq}, w_2^{eq})$ and $p_2^{eq} = p_2^{BR}(w_1^{eq}, w_2^{eq})$, the corresponding sales of each product, and the profits of each firm, for both scenarios M+M, M+PL.

We can thus compare the equilibrium values under both scenarios analytically, and describe quantitatively the effect of a private label introduction.

3.3 Best-Response Functions for Retailer and Manufacturers

In order to characterize the equilibrium in each scenario, we first need to determine the best response of the retailer when the manufacturers quote w_1, w_2. This best-response function is valid for both scenarios, since the only change is that in M+M, w_1, w_2 are both selected by the manufacturers, while in M+PL, w_1 is set by M1 but $w_2 = c_2$.

The retailer sets

$$\left(p_1^{BR}(w_1,w_2),p_2^{BR}(w_1,w_2)\right) = argmax_{p_1,p_2}\Pi_R(p_1,p_2,w_1,w_2)$$

which results in

$$p_i^{BR} = \frac{\alpha}{2\beta} + \frac{w_i}{2} \tag{4}$$

Thus, as one would expect, the retail prices that the retailer sets are linearly increasing in w_1, w_2, and do not depend on the substitution structure of the demand model. Indeed, since the cross-elasticities for 1 and 2 are identical, one's retail price is only a function of the product's wholesale price, and independent of the competitor's wholesale price.

As a result, q_1, q_2 are linear in w_1, w_2. In fact, after simplifying the algebra we obtain

$$q_i(p_i^{BR}, p_{-i}^{BR}) = \frac{1}{2}\Big(\alpha - \beta w_i - \theta(w_i - w_{-i})\Big)$$

This allows us to derive the optimal best-response function of a manufacturer:

$$w_i^{BR}(w_{-i}) = argmax_{w_1}\Pi_{Mi}(p_1^{BR}, p_2^{BR}, w_1, w_2)$$

or explicitly, for $i = 1, 2$,

$$w_i^{BR}(w_{-i}) = \frac{\alpha + \theta w_{-i}}{2(\beta+\theta)} + \frac{c_i}{2} \tag{5}$$

Note that this wholesale price is always larger than c_i whenever the quantity allocated to i is positive (this is the case for α large enough, as we assumed). Hence, one can see that the wholesale price w_i^{BR} quoted by a manufacturer is increasing in its own cost c_i and most importantly, increasing in the competitor's wholesale price w_{-i}, although any increase in w_{-i} results in a smaller increase in w_i^{BR} (less than half of it). This important feature implies that the manufacturer pricing game must have an equilibrium, and that this equilibrium is unique.

3.4 The Competitive Impact of Introducing a Private Label

As mentioned above, the manufacturer pricing game can be solved explicitly in the M+M scenario. The equilibrium is characterized by $w_1 = w_1^{BR}(w_2)$ and $w_2 = w_2^{BR}(w_1)$. Solving these equations yields the equilibrium values of

$$w_i^{M+M} = \frac{1}{2\beta+\theta}\left(\alpha + \frac{2(\beta+\theta)^2}{2\beta+3\theta}c_i + \frac{\theta(\beta+\theta)}{2\beta+3\theta}c_{-i}\right) \tag{6}$$

We thus we recover the results of Choi [4] Equation (2.8). Moreover, one can verify that when $\theta = 0$, we obtain the standard double marginalization result with one firm, i.e., $w_i^{eq} = \dfrac{\alpha}{2\beta} + \dfrac{c_i}{2}$. Finally, note that $w_i^{M+M} \geq c_i$ in order to guarantee that demand for product i is non-negative.

In contrast, under the M+PL scenario, the equilibrium is obtained by setting $w_2^{M+PL} = c_2$ and, from Equation (5),

$$w_1^{M+PL} = w_1^{BR}(c_2) = \frac{\alpha + \theta c_2}{2(\beta+\theta)} + \frac{c_1}{2} \leq w_1^{M+M} \tag{7}$$

This inequality is true since $w_2^{M+M} \geq c_2$, $w_1^{BR}(w_2)$ is increasing in w_2 and $w_1^{M+M} = w_1^{BR}(w_2^{M+M})$ and $w_1^{M+PL} = w_1^{BR}(c_2)$. As a result, we find that indeed the introduction of a private label increases the price pressure on the first manufacturer, M1. Thus in equilibrium M1's wholesale price is lower.

One of the central questions around the introduction of private labels is to determine whether the retailer and/or the manufacturers are better off. It turns out that M1 is worse off after the private label is introduced, and the coalition of M2 and the retailer is better off. In the M+M scenario the equilibrium sales of each brand $i = 1, 2$ is

$$q_i^{M+M} = \frac{\beta+\theta}{2(2\beta+\theta)} \left(\alpha - \frac{2\beta^2 + 4\beta\theta + \theta^2}{2\beta + 3\theta} c_i + \frac{\theta(\beta+\theta)}{2\beta+3\theta} c_{-i}\right)$$

and hence the equilibrium profit function of the manufacturers can be expressed as

$$\Pi_{Mi}^{M+M} = \frac{\beta+\theta}{2(2\beta+\theta)^2} \left(\alpha - \frac{2\beta^2 + 4\beta\theta + \theta^2}{2\beta + 3\theta} c_i + \frac{\theta(\beta+\theta)}{2\beta+3\theta} c_{-i}\right)^2 \tag{8}$$

while the equilibrium profit function of the retailer is

$$\Pi_R^{M+M} = \frac{(\beta+\theta)^2}{4\beta(2\beta+\theta)^2} \left[\sum_{i=1}^{2} \left(\alpha - \frac{2\beta^2 + 4\beta\theta + \theta^2}{2\beta + 3\theta} c_i + \frac{\theta(\beta+\theta)}{2\beta+3\theta} c_{-i}\right) \left(\alpha - \frac{2\beta(\beta+\theta)}{2\beta+3\theta} c_i - \frac{\theta\beta}{2\beta+3\theta} c_{-i}\right)\right]. \tag{9}$$

The profit functions in (8) and (9) extend Choi [4] to allow asymmetric production costs $c_i \neq c_j$ of the two manufacturers. However, if we set $c_i = c_j$, we recover the results of Choi [4] (in Choi's notation, we set $\gamma := \theta$ and $b := \beta + \theta$). In addition, we can calculate the supply chain profit as $\Pi_{SC} := \Pi_{M1} + \Pi_{M2} + \Pi_R$, hence

$$\Pi_{SC}^{M+M} = \frac{(\beta+\theta)(3\beta+\theta)}{4\beta(2\beta+\theta)^2} \times \left[\sum_{i=1}^{2} \left(\alpha - \frac{2\beta^2 + 4\beta\theta + \theta^2}{2\beta + 3\theta} c_i + \frac{\theta(\beta+\theta)}{2\beta+3\theta} c_{-i}\right) \left(\alpha - \frac{2\beta(3\beta^2 + 6\beta\theta + 2\theta^2)}{(3\beta+\theta)(2\beta+3\theta)} c_i + \frac{\beta\theta(\beta+\theta)}{(3\beta+\theta)(2\beta+3\theta)} c_{-i}\right)\right]. \tag{10}$$

In the M+PL scenario, the equilibrium sales are instead

$$q_1^{M+PL} = \frac{1}{4}\left(\alpha - (\beta+\theta)c_1 + \theta c_2\right) \text{ and } q_2^{M+PL} = \frac{2\beta+3\theta}{4(\beta+\theta)} \left(\alpha - \frac{2\beta^2 + 4\beta\theta + \theta^2}{2\beta+3\theta} c_2 + \frac{\theta(\beta+\theta)}{2\beta+3\theta} c_1\right).$$

The corresponding profit functions are $\Pi_{M2}^{M+PL} = 0$ because the second manufacturer is now charging the item at its cost,

$$\Pi_{M1}^{M+PL} = \frac{1}{8(\beta+\theta)}\left(\alpha - (\beta+\theta)c_1 + \theta c_2\right)^2 \tag{11}$$

and

$$\begin{aligned}\Pi_R^{M+PL} = \quad & \frac{\beta+2\theta}{16\beta(\beta+\theta)}\left(\alpha - (\beta+\theta)c_1 + \theta c_2\right)\left(\alpha - \frac{\beta\theta}{\beta+2\theta}c_2 - \frac{\beta(\beta+\theta)}{\beta+2\theta}c_1\right) \\ & + \frac{2\beta+3\theta}{8\beta(\beta+\theta)}(\alpha - \beta c_2)\left(\alpha - \frac{2\beta^2+4\beta\theta+\theta^2}{2\beta+3\theta}c_2 + \frac{\theta(\beta+\theta)}{2\beta+3\theta}c_1\right).\end{aligned} \tag{12}$$

Thus,

$$\begin{aligned}\Pi_{SC}^{M+PL} = \quad & \frac{3\beta+2\theta}{16\beta(\beta+\theta)}\left(\alpha - (\beta+\theta)c_1 + \theta c_2\right)\left(\alpha + \frac{\beta\theta}{3\beta+2\theta}c_2 - \frac{3\beta(\beta+\theta)}{3\beta+2\theta}c_1\right) \\ & + \frac{2\beta+3\theta}{8\beta(\beta+\theta)}(\alpha - \beta c_2)\left(\alpha - \frac{2\beta^2+4\beta\theta+\theta^2}{2\beta+3\theta}c_2 + \frac{\theta(\beta+\theta)}{2\beta+3\theta}c_1\right).\end{aligned} \tag{13}$$

We are now ready to compare the equilibrium prices, sales and profits on the two different scenarios, as shown in the next proposition.

Proposition 1. *Wholesale and retail prices are lower in M+PL compared to M+M. In addition, the branded product sells less and the private label more:* $q_1^{M+PL} \le q_1^{M+M}$ *and* $q_2^{M+PL} \ge q_2^{M+M}$*. This impacts profit in the following way:* $\Pi_{M1}^{M+PL} \le \Pi_{M1}^{M+M}$ *and* $\Pi_{M2}^{M+PL} + \Pi_R^{M+PL} \ge \Pi_{M2}^{M+M} + \Pi_R^{M+M}$.

The proof of the proposition is straightforward. One can observe that indeed, with the introduction of a private label by the retailer, manufacturer M1 reduces its wholesale price, and despite this, it still sells less since $q_1^{M+PL} - q_1^{M+M} = -\dfrac{\theta(\beta+\theta)q_2^{M+PL}}{(2\beta+\theta)(2\beta+3\theta)} \le 0$.

On the other hand, manufacturer M2 reduces its wholesale price to cost, as it becomes a private label supplier. This results in higher sales of the private label product. The joint profit of M2 and the retailer is now larger, since more sales volume moves to the private label, on which the retailer makes a higher margin.

We illustrate the change in the equilibrium values as a function of the cross-elasticity θ, for the situation where both manufacturers exhibit the same production cost. As θ increases, the intensity of competition increases since the same price gap between products results in higher substitution of the more expensive product for the cheaper product. Intuitively, a very high value of θ implies that the market is quite competitive, with low profits of the manufacturers in scenario M+M. As a result, introducing a private label in this setting introduces minimal changes the wholesale prices and quantities in equilibrium.

One can see in the left part of Figure 2 that retail and wholesale prices in the M+M scenario are identical and decrease. In the M+PL scenario, in contrast, the price of M1, w_1^{M+PL} is smaller than w_1^{M+M} and also decreases with θ; the difference $w_1^{M+M} - w_1^{M+PL}$ gets reduced with θ, since w_2^{M+M} approaches $w_2^{M+PL} = c_2$. Similarly, q_1^{M+PL} is smaller than q_1^{M+M} but the difference decreases with θ too. The right-hand side of Figure 2 shows the corresponding profits. Indeed $\Pi_{M1}^{M+PL} < \Pi_{M1}^{M+M}$, but the gap of these two profits gets smaller with θ, since as we pointed out above, both wholesale price and sales in the M+PL scenario approach the values in the M+M scenario. In contrast, the joint profits of retailer and M2 increase under the M+PL scenario, although again this increase is minimal when θ is large.

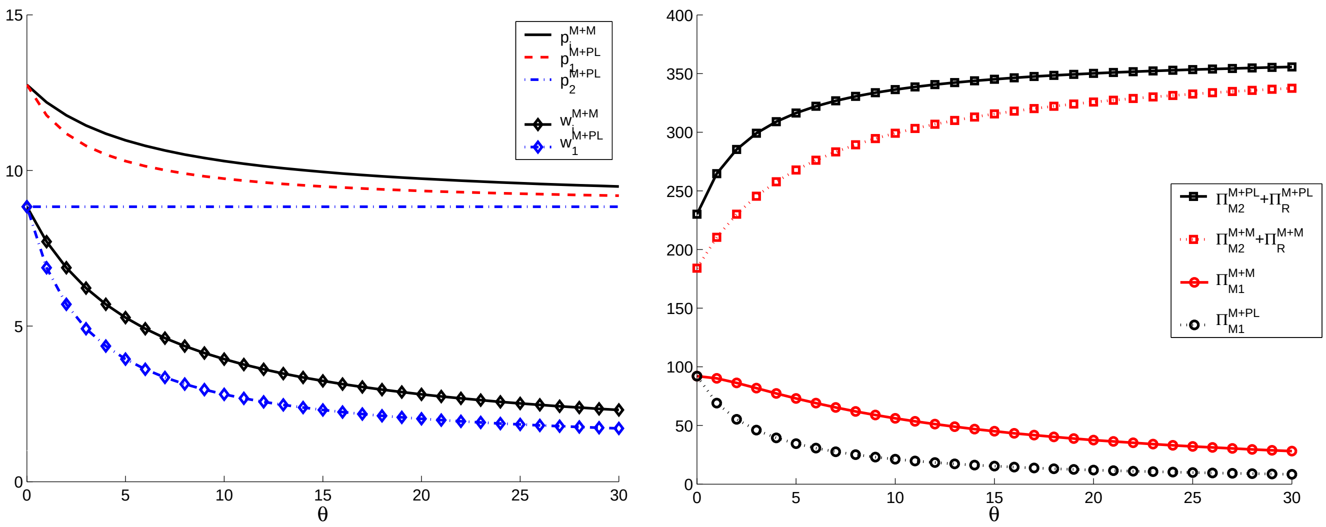

Figure 2: On the left-hand figure, retail price and wholesale price both products, under M+M and M+PL, for different values of θ; on the right-hand figure, profits of M1 and the coalition M2 plus R, for different values of θ. We use $\alpha = 50$, $\beta = 3$ and $c_1 = c_2 = 1$.

From the results above, we can highlight three main conclusions. First, the introduction of a private label will change the pricing dynamics in the channel. Indeed, this is equivalent to removing the double marginalization on the product, i.e., reducing the wholesale price w_2 to the true cost c_2. The strategic effect of this wholesale price reduction is a reduction of the wholesale price of the other manufacturer. Second, the private label will capture higher sales than before, through a larger demand due to lower retail price, but also through substitution of the branded product of M1 with the private label. The first product thus will reduce its sales. Third, the retailer is always better off by joining forces with a manufacturer through the introduction of a private label in terms of profits, which would explain why so many retailers are considering this type of action. In contrast, the other manufacturer in the category, M1, obtains lower profits. These three conclusions are prevalent in the literature, see Raju et al. [18] for instance.

3.5 Private Label and Supply Chain Efficiency

In the discussion above, we focused on the impact of a private label introduction on retailer and manufacturers. While retailer and M2 are doing better with the private label, M1 is doing worse. It is thus unclear whether the introduction of the private label is positive for the entire supply chain. The effect on the supply chain is in fact quite important since this is what determines in the long run the competitiveness of the players, which might be facing competition from other chains with a different private label strategy. As a result, guaranteeing that the private label improves supply chain profits is necessary. We investigate this issue next.

To build some intuition, the combined profit of manufacturers and retailer will always be smaller than that of a centralized chain, which is called the *first-best*. It is achieved by setting retail prices (p_1^*, p_2^*) that maximize the combined profit, i.e.,

$$\left(p_1^*, p_2^*\right) = argmax_{p_1,p_2}(p_1 - c_1)q_1(p_1, p_2) + (p_2 - c_2)q_2(p_1, p_2) = argmax_{p_1,p_2}\Pi_R(p_1, p_2, c_1, c_2)$$

In other words, $p_1^* = p_1^{BR}(c_1, c_2)$ and $p_2^* = p_2^{BR}(c_1, c_2)$. The first-best supply chain profit can then be expressed as

$$\Pi_{SC}^* = \frac{1}{4\beta}\left[\left(\alpha - \beta c_1\right)^2 + \left(\alpha - \beta c_2\right)^2 + \beta\theta(c_1 - c_2)^2\right] \tag{14}$$

Since in each scenario the equilibrium wholesale prices are higher than the cost, the equilibrium retail prices are higher than (p_1^*, p_2^*). As a result, sales are distorted as compared to the first-best:

- Total unit sales are lower than in the first-best;
- The mix of sales is different compared to that of the first-best, i.e., each individual product might sell more or less than in the first-best scenario.

These two effects create inefficiency for the supply chain: double marginalization in a two-product environment. Interestingly, the first effect (on total sales) is likely to be more important in M+M compared to M+PL, because prices are lower in M+PL. On the other hand, the second effect might actually be stronger in M+PL. Thus the overall efficiency of the M+M and M+PL equilibria will depend on the strength of this second effect. It ultimately depends on the price gap $\Delta := p_1 - p_2$ for each of the scenarios in equilibrium. In M+M,

$$\Delta^{M+M} := \quad p_1^{M+M} - p_2^{M+M} = \frac{(\beta+\theta)(2\beta+\theta)}{2(\beta^2+8\beta\theta+3\theta^2)}(c_1 - c_2).$$

Similarly,

$$\Delta^{M+PL} := p_1^{M+PL} - p_2^{M+PL} = \frac{\alpha}{4(\beta+\theta)} + \frac{1}{4}c_1 - \frac{2\beta+\theta}{4(\beta+\theta)}c_2.$$

Furthermore, observe that the price gap in the first-best is

$$\Delta^* := p_1^* - p_2^* = \frac{1}{2}(c_1 - c_2)$$

From these expressions, we observe that the price gap might indeed be higher under M+PL compared to M+M. For example, when the two manufacturers are symmetric, in the M+M equilibrium and in the first-best, the price gap is zero. In contrast, the price gap is positive under M+PL equilibrium.

Since we have explicit expressions of Π_{SC}^{M+M} and Π_{SC}^{M+PL}, we can compare the efficiency of the two scenarios. $\Pi_{SC}^{M+PL} - \Pi_{SC}^{M+M}$ is an intricate function of the parameters. For simplicity, we focus on the special case of $c_1 = c_2 = c$, where the expression simplifies to:

$$\Pi_{SC}^{M+PL} - \Pi_{SC}^{M+M} = \frac{(\alpha - c\beta)^2(4\beta^2 + 4\beta\theta - \theta^2)}{16(\beta+\theta)(2\beta+\theta)^2} \tag{15}$$

Under symmetric costs, Figure 3 illustrates the value of Π_{SC}^{M+M} and Π_{SC}^{M+PL} as a function of the cross-elasticity θ. It is worth observing that $\Pi_{SC}^{M+PL} > \Pi_{SC}^{M+M}$ if and only if θ is lower than a certain threshold. This is intuitive: for low substitution levels, the scenario M+M results in low efficiency since the manufacturers quote prices that are too high, while the scenario M+PL is effective in reducing M1's wholesale price and hence yields higher efficiency. In fact, the threshold can be explicitly calculated as stated in the next proposition.

Proposition 2. *When $c_1 = c_2$, $\Pi_{SC}^{M+PL} \geq \Pi_{SC}^{M+M}$ if and only if $\theta \leq \bar{\theta}$ where*

$$\bar{\theta} = 2(1+\sqrt{2})\beta. \tag{16}$$

The threshold is found by setting the expression in (15) to zero. Figure 3 illustrates the proposition. For the values used in the figure, $\bar{\theta} \approx 14.5$. The proposition implies that in product categories with higher price elasticity β, there is a wider range of product substitutability for which total supply chain profit will be higher with a private label case than without it. These results indicate that the retailer not only has a personal interest in introducing a private label (because it improves its profits), but also has a very strong incentive to introduce a private label into a product category with high price elasticity for the sake of supply chain efficiency. Finally, it is worth noting that a similar conclusion has been observed under different settings, when there is quality differentiation of private label and manufacturer brand and development costs for the introduction of the private label, see Chen et al. [5].

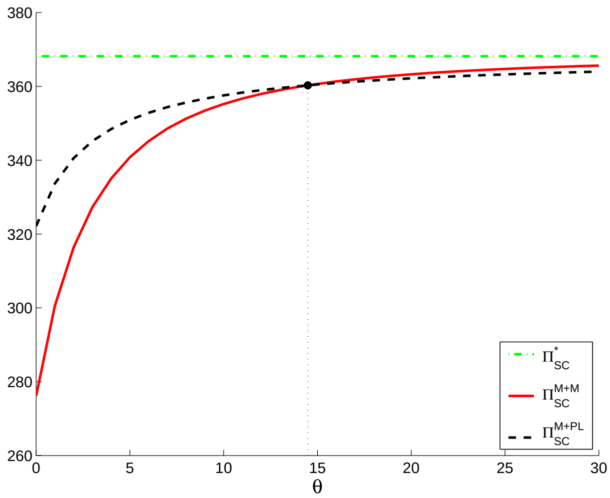

Figure 3: Total supply chain profits for the two scenarios, together with the first-best profit Π^*_{SC}. We use $\alpha = 50$, $\beta = 3$ and $c_1 = c_2 = 1$.

More generally, when $c_1 \neq c_2$, numerical simulations indicate that the same insight holds true: it is beneficial for the supply chain to introduce a private label only when θ is lower than a threshold. In that case, however, we have to bear in mind that the area for which sales are positive (recall that α must be large enough) imposes a constraint on the possible values that θ can take. Specifically, θ cannot be larger than a certain value θ_{max} that depends on α. [2] Thus, from our numerical experiments, we find a threshold $\bar{\theta} \leq \theta_{max}$ such that for $0 \leq \theta \leq \bar{\theta}$, $\Pi^{M+PL}_{SC} \geq \Pi^{M+M}_{SC}$, while $\Pi^{M+PL}_{SC} \leq \Pi^{M+M}_{SC}$ for $\bar{\theta} \leq \theta \leq \theta_{max}$.

4 Application to More General Settings

4.1 General Demand Models

The demand in §3 was specified as a linear function, for two reasons: first, it allows an analytical study of equilibrium prices, quantities and profits, which generates insights; second, it approximates locally real demands, which implies that the conclusions reached above apply provided that the approximation is accurate in the vicinity of both the M+M and M+PL equilibria. In this section, we generalize the demand model and characterize the conditions under which the results of §3 continue to apply. Note that the analysis of general demand functions

[2] θ_{max} is the solution of $q_i^{M+PL} = 0$, where i is the high-cost firm. Hence, if $c_1 > c_2$, it is the solution of $\alpha - (\beta+\theta)c_1 + \theta c_2 = 0$, i.e., $\theta_{max} = \dfrac{\alpha - \beta c_1}{c_1 - c_2} > 0$. If $c_1 < c_2$, it is the positive solution of $(2\beta + 3\theta)\alpha - (2\beta^2 + 4\beta\theta + \theta^2)c_2 + \theta(\beta + \theta)c_1 = 0$.

in a duopoly quickly becomes intractable, as pointed out by Choi [4]. Because of this, we focus on identifying the structural conditions that preserve the problem's structure.

For this purpose, we consider a general demand structure $q_i(p_1, p_2)$ that replaces Equation (1). In order to simplify the exposition for this general case, we transform this price-dependent demand into a quantity-depend retail price, denoted r_i, $i = 1, 2$:

$$r_1(q_1, q_2) \text{ and } r_2(q_1, q_2) \text{ such that for } i = 1, 2, r_i\Big(q_i(p_1, p_2), q_{-i}(p_1, p_2)\Big) = p_i \text{ for all } p_i, p_{-i} \tag{17}$$

Following Singh and Vives [21], if the two products are substitutes (the cross-price-elasticity is positive), then r_i is decreasing in q_1 and q_2 (the cross-quantity elasticity is negative). For example, for the linear case,

$$r_i(q_1, q_2) = \frac{\alpha}{\beta} - \frac{\beta + \theta}{\beta(\beta + 2\theta)} q_i - \frac{\theta}{\beta(\beta + 2\theta)} q_{-i}.$$

The retailer's profit can be written as $\Pi_R(q_1, q_2, w_1, w_2) = (r_1(q_1, q_2) - w_1)q_1 + (r_2(q_1, q_2) - w_2)q_2$. In order to preserve the structure of the analysis, we need first to guarantee that the retailer's problem is concave. This is true if and only if for all q_1, q_2 for which $r_1, r_2 \geq 0$,

$$H(q_1, q_2) := \begin{pmatrix} 2\frac{\partial r_1}{\partial q_1} + q_1 \frac{\partial^2 r_1}{\partial q_1^2} + q_2 \frac{\partial^2 r_2}{\partial q_1^2} & \frac{\partial r_1}{\partial q_2} + \frac{\partial r_2}{\partial q_1} + q_1 \frac{\partial^2 r_1}{\partial q_1 \partial q_2} + q_2 \frac{\partial^2 r_2}{\partial q_1 \partial q_2} \\ \frac{\partial r_1}{\partial q_2} + \frac{\partial r_2}{\partial q_1} + q_1 \frac{\partial^2 r_1}{\partial q_1 \partial q_2} + q_2 \frac{\partial^2 r_2}{\partial q_1 \partial q_2} & 2\frac{\partial r_2}{\partial q_2} + q_1 \frac{\partial^2 r_1}{\partial q_2^2} + q_2 \frac{\partial^2 r_2}{\partial q_2^2} \end{pmatrix} \preceq 0, \tag{18}$$

i.e., the retailer's profit Hessian matrix is negative semi-definite. If this is not satisfied, then the best-response retail prices might be discontinuous in the wholesale prices, which does not guarantee existence of the manufacturer's price equilibrium. Fortunately, the condition is satisfied in most common situations, for example when r_i is jointly concave in (q_1, q_2) in the region where it is positive, and $\frac{\partial r_1}{\partial q_1} \frac{\partial r_2}{\partial q_2} \geq \left(\frac{1}{2} \frac{\partial r_1}{\partial q_2} + \frac{1}{2} \frac{\partial r_2}{\partial q_1} \right)^2$, i.e., cross-quantity elasticities are not too large.

Under these circumstances, we can define the retailer's sales allocation q_1^{BR}, q_2^{BR} as a function of the wholesale prices, through first order conditions. Implicit differentiation of these yields that

$$\frac{\partial q_i^{BR}}{\partial w_i} = \frac{H_{ii}(q_1^{BR}, q_2^{BR})}{\det\Big(H(q_1^{BR}, q_2^{BR})\Big)} \leq 0$$

and

$$\frac{\partial q_i^{BR}}{\partial w_{-i}} = \frac{-H_{12}(q_1^{BR}, q_2^{BR})}{\det\Big(H(q_1^{BR}, q_2^{BR})\Big)} \geq 0. \tag{19}$$

Each manufacturer now faces the problem of maximizing $(w_i - c_i)q_i^{BR}$. This is well-behaved when for all w_i, $i = 1, 2$,

$$2\left(\frac{\partial q_i^{BR}}{\partial w_i}\right)^2 \geq q_i^{BR}\frac{\partial^2 q_i^{BR}}{\partial w_i^2}, \tag{20}$$

and under this condition we can define uniquely $w_i^{BR}(w_{-i})$, which is continuous function. In addition, a sufficient condition for the wholesale price equilibrium to be unique is that for $i = 1, 2$,

$$0 \leq \frac{dw_i^{BR}}{dw_{-i}} < 1, \tag{21}$$

which is true in the linear demand case.

Under the three conditions of Equations (18), (20) and (21), the introduction of the private label always reduces the equilibrium wholesale price of M1, since $w_1^{BR}(w_2)$ is increasing and $w_2^{M+M} \geq c_2 = w_2^{M+PL}$.

The impact on profit can also be established. Letting $\Pi_{M1}(w_2) = (w_1^{BR}(w_2) - c_1)q_1^{BR}(w_1^{BR}(w_2), w_2)$, $\Pi_{M2}(w_2) = (w_2 - c_2)q_2^{BR}(w_1^{BR}(w_2), w_2)$ and $\Pi_R(w_2) = \max_{q_1,q_2}\left\{\left(r_1 - w_1^{BR}(w_2)\right)q_1 + (r_2 - w_2)q_2\right\}$, we conclude that the profit of M1 is reduced as well since $\Pi_{M1}^{M+M} = \Pi_{M1}(w_2^{M+M})$, $\Pi_{M1}^{M+PL} = \Pi_{M1}(c_2)$ and, from the envelope theorem, $\dfrac{\partial \Pi_{M1}(w_2)}{\partial w_2} = (w_1^{BR}(w_2) - c_1)\dfrac{\partial q_1^{BR}}{\partial w_2} \geq 0$. Similarly, the joint profit of M2 and the retailer increases since

$$\frac{\partial \Pi_R}{\partial w_2} = -\frac{\partial w_1^{BR}}{\partial w_2}q_1 - q_2 \leq -q_2$$

and

$$\frac{\partial \Pi_{M2}}{\partial w_2} = q_2 + (w_2 - c_2)\frac{\partial q_2^{BR}}{\partial w_2} \leq q_2.$$

The impact of a private label introduction on supply chain profit is more difficult to evaluate. Generally, letting $\Pi_{SC}(w_2) = \Pi_{M1}(w_2) + \Pi_{M2}(w_2) + \Pi_R(w_2)$,

$$\frac{\partial \Pi_{SC}}{\partial w_2} = (w_1^{BR}(w_2) - c_1)\frac{\partial q_1^{BR}}{\partial w_2} - \frac{\partial w_1^{BR}}{\partial w_2}q_1 + (w_2 - c_2)\frac{\partial q_2^{BR}}{\partial w_2}.$$

When the first term in this expression is large, $\dfrac{\partial \Pi_{SC}}{\partial w_2} > 0$, and hence $\Pi_{SC}^{M+PL} = \Pi_{SC}(c_2) \leq \Pi_{SC}^{M+M} = \Pi_{SC}(w_2^{M+M})$. This occurs when the cross-elasticity is large, see Equation (19). In this respect, the result of Proposition 2 is qualitatively preserved under the general demand model: the supply chain will benefit from the introduction of the private label only when the quantity cross-elasticity is small, i.e., when the products are weak substitutes.

4.2 Categories with more than Two Products

Another simplification that was made in the model for the sake of tractability was to consider only two manufacturers. In this section, we relax this assumption to have n products. The M+M scenario thus extends to the price equilibrium of n manufacturers, while the M+PL scenario becomes the price equilibrium between $n-1$ manufacturers and one private label sold at cost (for consistency, the brand replaced by the private label is item n). We replace the demand function of (1) by

$$q_i(p_1, \ldots, p_n) = \alpha - \beta p_i - \sum_{j \neq i} \theta(p_i - p_j) \text{ for } i = 1, \ldots, n \tag{22}$$

Note that in this demand function, product cross-elasticities are constant, as in the n-manufacturer model of Raju et al. [18]. Again, to prevent negative sales, we assume that α is large enough. In order to maximize its profits, the retailer sets

$$p_i^{BR} = \frac{\alpha}{2\beta} + \frac{w_i}{2}$$

which is identical to Equation (4) due to the fact that the cross-elasticities are all identical. Thus, the sales of the manufacturers as a function of $(w_1, \ldots, w_n)$ are

$$q_i = \frac{1}{2}\left(\alpha - \beta w_i - \sum_{j \neq i} \theta(w_i - w_j)\right)$$

Hence, the best-response of i to $w_{-i} = (w_1, \ldots, w_{i-1}, w_{i+1}, \ldots, w_n)$ becomes

$$w_i^{BR}(w_{-i}) = \frac{\alpha + \theta \sum_{j \neq i} w_j}{2(\beta + (n-1)\theta)} + \frac{c_i}{2} \geq c_i \tag{23}$$

which replaces Equation (5). The equilibrium value in the M+M scenario thus becomes

$$\begin{aligned} w_i^{M+M} = \quad & \frac{1}{2\beta + (n-1)\theta} \\ & \times \left(\alpha + \frac{(\beta + (n-1)\theta)(2\beta + n\theta)}{2\beta + (2n-1)\theta} c_i + \frac{(\beta + (n-1)\theta)\theta}{2\beta + (2n-1)\theta} \sum_{j \neq i} c_j\right) \end{aligned} \tag{24}$$

which extends Equation (6). Similarly,

$$\begin{aligned} w_i^{M+PL} = \quad & \frac{1}{2\beta + n\theta} \\ & \times \left(\alpha + \frac{(\beta + (n-1)\theta)(2\beta + (n+1)\theta)}{2\beta + (2n-1)\theta} c_i + \frac{(\beta + (n-1)\theta)\theta}{2\beta + (2n-1)\theta} \sum_{j \neq i, j \neq n} c_j + \theta c_n\right) \end{aligned} \tag{25}$$

extends Equation (7). It is again simple to verify that $c_i \leq w_i^{M+PL} \leq w_i^{M+M}$, although the decrease in equilibrium prices becomes smaller as n increases. This is intuitive because with a larger n, the price competition inside the category is stronger to start with, and hence introducing a private label only adds little additional competition.

It is interesting to understand the effect of the number of products in the category on equilibrium prices, quantities and profits. Figure 4 illustrates the variation of these quantities as a function of $n \geq 2$. One can indeed observe that, as n increases, the category becomes more competitive, i.e., prices converge to cost. At the same time, while the insights of Proposition 1 continue to apply, we observe that the benefits of introducing the private label for the supply chain become negative when n is large enough. This insight goes in the same direction of Proposition 2: when competition in the category is strong enough without the private label (either because there is strong substitution between items or there are many players competing), introducing one distorts the competition, increases aggregate sales only marginally, but shifts volume from the brands toward the lower-priced private label item so that total revenue might decrease.

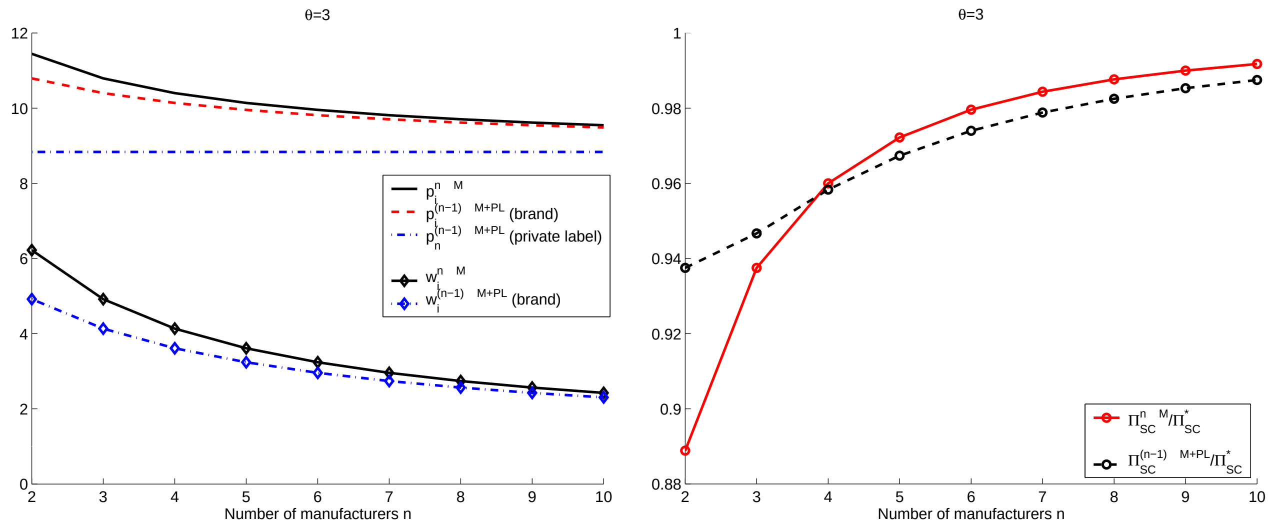

Figure 4: On the left-hand figure, equilibrium wholesale price under nM and (n-1)M+PL; on the right-hand figure, profits of M1 and the coalition M2 plus R. We plot these functions for different values of n, the number of products in the category. We use $\alpha = 50$, $\beta = 3$, $\theta = 3$ and $c_i = 1$ for $i = 1, \ldots, n$.

5 Conclusions

In this paper, we have presented a simple model to evaluate the effect on supply chain performance of a private label introduction, in one category. The analytical results derived with game theory coincide with empirical evidence: the introduction of a private label product into a product category forces the incumbent manufacturer brand to a strategic price reduction, due to the price elasticity and cross-elasticities of the demand curves. This reduces the rents realized by the manufacturer brand. The rate of price reduction of the manufacturer brand is more pronounced when there is little substitution between the manufacturer brand and private label product (i.e., a small θ). As product substitutability increases, the brand manufacturer lowers its wholesale prices at a decreasing rate, to finally approach the variable production cost for large θ.

One of the main conclusions derived from our model is that the supply chain might be worse off after the retailer replaces one manufacturer brand by a private label. Indeed, while introducing the private label reduces prices and the double marginalization effect on total sales, it also distorts the price gap between the two items in the category, which might drive too many sales to the private label, thereby reducing supply chain profit. We found that the introduction of private label is only beneficial for low values of product substitutability θ, and we identified the threshold $\bar{\theta}$ after which private label will hurt supply chain performance.

The basic model considers only two players and linear demand functions, but we extend these insights to more general situations, see §4. In particular, we find that the introduction of a private label generally reduces supply chain profit when the competition in the category is initially strong. This is the case when product substitution is high or the number of players in the category is large. These extensions show that our conclusions are robust, and hence constitute general recommendations for retail supply chains.

While our model adds to the growing literature of private labels in retail, it opens a number of possible lines for future work. First, we identify the strategic impact of private label introduction on category prices. However, there are other side effects that may be as important as prices: shelf space allocations, product placement and promotional activities. These are short-term decisions that manufacturers base on what competitors do, and are likely to be influenced by the replacement of a brand manufacturer by a private label controlled by the retailer. In this respect, continuous analytical models can shed light on how these operational and marketing variables change with private labels. Second, the introduction of private labels is usually followed by a rationalization of the category, i.e., the number of items in the assortment is modified. It would be interesting to model the retailer's optimal assortment with and without private label to evaluate the changes for all players in the category and the supply chain.

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