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Decision Support

Impacts of store-brand introduction on a multiple-echelon supply chain

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ABSTRACT

Observing that store brands are often introduced in multiple-echelon supply chains, however, the common wisdom from analytical models on store brands has been obtained from two-echelon supply chains, we investigate the strategic interaction in a three-echelon supply chain (manufacturer-distributer-retailer) with a store brand and its corresponding impacts. This research reveals the ways in which store brand affects the interaction and performance of the three-echelon supply chain, as it is significantly different from the two-echelon case. In particular, when the store brand is moderately competitive, the nature of the interaction between the national-brand manufacturer and the distributer can change from dependence to independence, enabling the national-brand manufacturer to manipulate its price leadership to increase its wholesale price instead, leaving the distributer itself to deter the SB introduction. Consequently, the distributer plays a special role as a buffer between the national-brand manufacturer and the retailer. When the store brand is competitive enough and finally introduced, all channel members may benefit from the store brand introduction, but this phenomenon never occurs in the two-echelon case under the same conditions. Therefore, this study increases our understanding of how store brand affects the multiple-echelon supply chain and provides another important theoretical explanation for why executive managers of national brand products need not overreact to the introduction of their retailers' store brands.

1. Introduction

Store brands (SB) or private labels, named and controlled by retailers exclusively for their stores, have illustrated continuous growth in Europe, North America and Australia. According to the 2019 International Private Label Yearbook of Private Label Manufacturers Association (PLMA), Spain, Switzerland and the United Kingdom lead the way with the highest SB market shares (volume) at or above 50% of the 20 countries in Europe (PLMA, 2019). In the US, SB grew by 4.4%, four times as much as national brands (NB), and SB market penetration set all-time records, advancing to 18.5% in dollar share and 22.3% in volume share, which brings the total SB sales to about 170 billion (Storebrands-Facts, 2019).

How does an SB affect the performance of a supply chain and its individual members? Both analytical models and empirical studies (Ailawadi, Pauwels, & Steenkamp, 2013; Bontems, Monier-Dilhan, & Réquillart, 1999; Chintagunta, Bonfrer, & Song, 2002; Dhar & Hoch, 1997; Groznik & Heese, 2010; Mills, 1995; Morton & Zettelmeyer, 2004; Narasimhan & Wilcox, 1998; Pauwels & Srinivasan, 2004; Ru, Shi, & Zhang, 2015; Sivakumar, 1996) widely agree that SBs benefit the whole channel by alleviating the double marginalization problem for NBs and retailers by strengthening their bargaining power vis-à-vis the NB manufacturers and discriminating consumers with two differentiated brands. For NB manufacturers, however, there seems to be some discrepancies. Most extant analytical models conclude that NB manufacturers suffer from SBs, because of the lowered NB wholesale prices and eroded demand. Empirical studies, on the other hand, find that NB manufacturers may not always be hurt by SBs. As a matter of fact, they may benefit from SB entry in the form of increased wholesale prices or demand (Bonfrer & Chintagunta, 2004; Nielsen, 2014; Pauwels & Srinivasan, 2004).

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Nielsen (2014) states that typically category leaders are not challenged by SB cannibalization. Taking the UK for example, on average, 40% of sales come from the category leader, 41% from SBs and 19% from all other brands.

To determine the theoretical explanations for these discrepancies, Gabrielsen and Sørgard (2007) take consumers' brand loyalty into account and model the manufacturer-retailer interaction as a manufacturer-led Stackelberg game. They find that the NB manufacturer would increase the wholesale price to stop serving the switching consumers due to SB entry. Nevertheless, the NB manufacturer still suffers from SB introduction with a much lowered NB demand. Ru et al. (2015) observe that these discrepancies may be caused by the supply chain power structure. As such, they model the manufacturer-retailer interaction as a retailer-led Stackelberg game, showing that both the NB wholesale price and demand may increase after SB entry, and thus, benefit the NB manufacturer. By manipulating the strategic timing of pricing and advertising decisions, Karray and Martín-Herrán (2019) reveal that the NB manufacturer may prevent or benefit from the SB introduction. When considering spillover effect between NB and SB in-store promotion (Zhou, Liu, & Cai, 2019) or between different SB categories (Alan, Kurtulus, & Wang, 2019), the SB introduction may also benefit the NB manufacturer.

Note that all the analytical research mentioned above related to SB has been conducted in the context of two-echelon supply chains, composed only of NB manufacturers and retailers. In reality, three-echelon supply chains, or even multiple-echelon supply chains, are not uncommon. In the market, SBs products are very often introduced by retailers in the fast-moving consumer goods (FMCG), typically including foods, snacks and beverages; health and beauty; and household products of all types (PLMA, 2020). FMCG manufacturers, such as Unilever or Procter & Gamble, Coca Cola, Nestle, mainly adopt the distribution mode of middlemen (distributers, wholesalers) (Kotler & Armstrong, 2016; Pötzl, 2000). Many Chinese local NB manufacturers (e.g. Laoganma Flavor Food, Snow Beer) also distribute the products to the retailers (such as Walmart and Carrefour in China) through regional distributers. Theoretically, Chen, Deng, and Huang (2014) demonstrate that distributers play a vital role as an information intermediary and thus are never excluded from supply chains. Actually, increasing research (Chen et al., 2014; Giannoccaro & Pontrandolfo, 2004; Hou, Wei, Li, Huang, & Ashley, 2017; Leng & Parlar, 2009; Munson & Rosenblatt, 2001; Panda, Modak, Basu, & Goyal, 2015) has been performed in three-echelon settings for traditional supply chains (i.e. supply chains without SBs). It is found that the corresponding insights are specific to three-echelon supply chains and distinct from the two-echelon setting.

With this observation, what motivated us to investigate the impacts of SB introduction in the context of multiple-echelon supply chain is: existing theoretical studies regarding SB are all conducted in two-echelon supply chains, however, the real business practice related to SB mainly appears in FMCG field where multiple-echelon supply chains dominate, and then the supply chain layer structure may result in different impacts of SB introduction on supply chain performance. On the other hand, the insights from the retailer-led Stackelberg game model (Ru et al., 2015) fail to explain why typically category leaders (the manufacturer-led Stackelberg game) may not suffer from the SB introduction (Nielsen, 2014; Pauwels & Srinivasan, 2004). When the strategic timing of pricing and advertising decisions (Karray & Martín-Herrán, 2019) or spillover effect (Alan et al., 2019; Zhou et al., 2019) do not count, all manufacturer-led Stackelberg game models predict that NB manufacturers are hurt by the SB introduction. Therefore, the discrepancies between the theoretical predictions and empirical studies may be caused by different supply chain layer structures. In other words, the existence of distributers may be another reason why NB manufacturers may benefit from their competing SBs. In particular, Govindan and Popiuc (2014) reveal that the presence of the distributer in a reverse supply chain can affect the profit of the manufacturer. Analogously, to the best of our knowledge, other theoretical results regarding the impacts of SB entry are also obtained in the two-echelon supply chain setting. Thus, whether the results can be applied to the three-echelon supply chain remains unclear. Especially, how the distributer reacts to and is affected by the SB introduction is completely in the dark. Therefore, there is a clear need for advancing our understanding of the impacts of SB introduction on the three-echelon supply chain. To this end, our study attempts to explore the following questions:

(i) Is SB more or less likely to be introduced by the retailer in the three-echelon supply chain compared with the two-echelon supply chain, and why?
(ii) How do the NB manufacturer, the distributer and the retailer interact with each other in the presence of SB?
(iii) Can SB introduction alleviate the triple-marginalization problem inherent in the three-echelon supply chain? And how does SB introduction affect the performance of the whole channel differently compared with the two-echelon case?
(iv) Does a leading NB manufacturer always suffer from SB introduction, as it does in the two-echelon supply chain? How about the distributer?

To address these questions, game theory is used to model the interaction between an NB manufacturer, a distributer and a retailer with and without the SB option in a three-echelon supply chain. The manufacturer-distributer-retailer interaction is modeled as a three-stage Stackelberg game. To make our game easier to follow, we take Laoganma Flavor Food, a very popular and well-known chilli sauce maker in China, as an example. When Laoganma (the NB manufacturer) distributes its chilli sauce (NB) to a local Walmart supermarket in Shanghai (the retailer) by a local distributer (the distributer), Walmart considers whether to introduce its own chilli sauce (SB) to compete with Laoganma or not. Actually, Walmart has already released its own chilli sauce with the "Great Value" brand into the Chinese market. Accordingly, Laoganma-the local distributer-Walmart consists of a three-echelon supply chain, and the strategic interaction between them when making pricing decision can be modeled by game theory as a three-stage Stackelberg game.

In this game, the NB manufacturer acts as a Stackelberg leader and makes its pricing decision with the anticipation of other supply chain partners' reactions when wholesaling its NB product to the distributer. In turn, given the NB wholesale price from the NB manufacturer, and anticipating the reaction of the retailer, the distributer determines its wholesale price to the retailer. At last, the retailer makes decisions on the SB introduction and retail pricing conditionally on the other two partners' actions. As most literature does (Fang, Gavirneni, & Rao, 2013; Mehta, Chen, & Narasimhan, 2008; Narasimhan & Wilcox, 1998; Ru et al., 2015), we make the assumption that the retailer's SB introduction decision is a short-term one that can be adjusted according to the pricing strategy. In addition, an assumption that SBs are typically more inexpensive than NBs (although premium SBs are increasingly appealing to retailers) is also made. For instance, by polling more than 30,000 online consumers in 60 countries, Nielsen found that price was important to most consumers and was the primary driver of consumers purchase intent for private labels. Approximately 70% of consumers said they purchase SB to save money (Nielsen, 2014), and the SB volume share (22.3%) was much higher than the dollar share (18.5%) in the US (Storebrands-Facts, 2019). In line with these observations, we focus our study by assuming that SB has a lower perceived quality than NB and is deemed to be an imperfect substitute for NB.

Investigating the impacts of SB introduction on a three-echelon supply chain represents an important departure from the analytical studies on SB, and contributes to the existing literature with following new insights. First, when with an SB not too competitive, the nature of strategic interaction between the NB-manufacturer and the distributer might change from dependence to independence. Consequently, the NB-manufacturer can manipulate its price leadership to increase its wholesale price, leaving the distributer alone to prevent the SB introduction. Second, compared with a two-echelon supply chain, the SB introduction improves more performance of a three-echelon supply chain, in the form of more profit from the SB products instead of NB products. Most surprisingly, we find that all supply chain members may benefit from SB introduction even though NB wholesale prices are lowered, which never happens in the two-echelon case under the same conditions.

The rest of this paper is structured as follows. The related literature is reviewed in Section 2. The detailed assumptions and the model are described in Section 3. Games in the two- and three-echelon supply chains are solved and the equilibrium results are presented in Section 4. The impacts of the SB introduction on the three-echelon supply chain are analyzed and the differences in these impacts from the two-echelon supply chain are compared in Section 5. In the final section, we draw our conclusions and offer some possible extensions of our model for future research.

2. Literature Review

In practice, supply chains are far more complicated than two-echelon chains consisting of only manufacturers and retailers. To approach the real word, there is growing literature that has begun to investigate multi-echelon supply chains. We follow this lead and investigate a three-echelon supply chain. The early work in this area dates back to Munson and Rosenblatt (2001), who propose a quantity discounts mechanism to coordinate a supplier-manufacturer-retailer chain. Based on Munson and Rosenblatt's work, Jaber, Osman, and Guiffrida (2006) prove that a three-echelon supply chain with a price dependent demand can be coordinated by a profit sharing mechanism combined with a quantity discounts scheme. Differentiated from one revenue sharing contract needed to coordinate a two-level supply chain, Giannoccaro and Pontrandolfo (2004) propose a two-revenue-sharing-contract to coordinate a three-level supply chain made up of a manufacturer, a distributer and a retailer. Similarly, a revenue sharing contract is also applied by Govindan and Popiuc (2014), however, to coordinate a reverse three-echelon supply chain. Wu and Cheng (2008) investigate how information sharing affects a multiple-echelon supply chain consisting of a manufacturer, a distributer and a retailer. For the same supply chain, Leng and Parlar (2009) construct a cooperative game to analyze the problem of allocating cost savings from sharing demand information. Chen et al. (2014) study the role of distributers as an information intermediary in a three-stage supply chain comprised of a supplier, a number of distributers, and a continuum of retailers. When corporate social responsibility is exhibited, Panda et al. (2015) analyze how to coordinate a manufacturer-distributer-retailer supply chain. For more studies on three-echelon supply chains, the interested reader can refer to Ding and Chen (2008), Seifert, Zequeira, and Liao (2012), Panda, Modak, and Basu (2014), Modak, Panda, and Sana (2016), Giri, Bardhan, and Maiti (2016). Similar to this stream of research, we also investigate the interaction in a multi-echelon supply chain, specifically a three-echelon supply chain. However, we extend this stream of work by identifying the impacts of the SB introduction on the interactions and performance of the supply chain members. SBs retailers are no longer the sole vertical partners but are also direct competitors with respect to the NB manufacturers (Dhar & Hoch, 1997; Quelch & Harding, 1996). This makes the relationship between the retailers and NB manufacturers fairly special and distinctive from that of the supply chains without SBs. Therefore, we obtain some very interesting and fresh new insights based on this research.

Due to the accelerating growth of SBs in the market as stated in the opening, extensive attention has been paid to the research regarding SBs. The most closely related work is the analytical research exploring the impacts of SB introduction on supply chains and individual channel members. Mills (1995) conducted a seminal work to study the interaction between an NB-manufacturer and a retailer who has an option for its SB. Mills concludes that SB can lead to a decrease in the NB wholesale price, and thus, overcome the double-marginalization problem on the NB supply chain at the expense of the NB manufacturer's profit. Mills (1999) makes a similar conclusion under the same supply chain structure, but focuses on the NB manufacturer's counter-strategies to the SB's impacts. In similar settings and with similar conclusions, Narasimhan and Wilcox (1998) take consumers' brand loyalty into account and characterize the switching consumers with the willingness-to-switch price difference between SB and NB, instead of the willingness-to-pay for NB in the Mills (1995, 1999). Gabrielsen and Sørgard (2007) also consider consumers' brand loyalty and the impacts of SB introduction while from the perspective of consumers and society. They reveal that SB introduction may lead to an increase in the NB wholesale price, and therefore, hurt consumers. By modelling the manufacturer-retailer interaction as a retailer-led Stackelberg game, Ru et al. (2015) demonstrate that SB introduction can lessen the double marginalization problem by benefiting the NB manufacturer with an increase in both NB wholesale price and demand.

Differing from the above research, with one manufacturer and one retailer, some other studies consider more market-like settings by incorporating competition among NB manufacturers or among retailers. Raju, Sethuraman, and Dhar (1995) investigate a supply chain with two symmetric NB manufacturers and a retailer and then extends the investigation to multiple symmetric NB manufacturers, finding that the SB profitability and market share depend on the cross-price sensitivity both among NBs and between NBs and SB. Sayman, Hoch, and Raju (2002), Morton and Zettelmeyer (2004), Choi and Coughlan (2006) all examine how a retailer should strategically position its SB when there are two asymmetric NB manufacturers. With a similar supply chain structure, both Wu and Wang (2005) Lewin, Tomas Gomez-Arias, and Bello-Acebron (2008) study SB production arrangement issues. In a supply chain with two competing retailers and a common NB manufacturer, Corstjens and Lal (2000) show that quality SB can serve as an instrument to generate store loyalty, as well as an implicit coordination mechanism between all retailers. Tarzijn (2004) investigates the impact of retail market concentration on the SB performance when there are multiple symmetric retailers in a Cournot quantity competition. In a supply chain with a single NB manufacturer distributing its product simultaneously from a single retailer and its self-controlled e-channel, Kurata, Yao, and Liu (2007) explore the cross-brand and cross-channel pricing policies and channel coordination mechanism. Groznik and Heese (2010) use a numerical simulation to study how retail competition affects the impacts of SB on supply chain interactions between two retailers and a common NB manufacturer. Likewise, with two competing retailers and an NB manufacturer in the supply chain, Choi and Fredj (2013) model store competition between retailers, in addition to product competition between SBs and NBs.

Most recently, the strategic interaction between channel choice and the SB introduction (Jin, Wu, & Hu, 2017; Li, Zhang, Chiu, Liu, & Sethi, 2019) and the SB quality optimization by strategic souring (Bo, Candace A., & Minakshi, 2020) or extended warranty (Mai, Liu, Morris, & Sun, 2017) are studied. Again, all the above research is conducted in the context of two-echelon supply chains. Echoing Sethuraman (2009) who calls for the consideration of more realistic market conditions in the analytical models, and being consistent with the real markets where multi-echelon supply chains prevail, we extend the existing work regarding SB by adding a third echelon to the supply chain and model the interaction in a three-echelon supply chain consisting of a single NB manufacturer, a single distributer and a single retailer with an SB introduction option. We show that the distributer plays a special role in this interaction, and thus, may result in both the NB manufacturer and itself benefiting from the SB introduction.

3. Assumptions and Demand Model

Consider a three-echelon supply chain involving an NB manufacturer, an NB distributer and a retailer. The NB manufacturer produces the NB products at a unit variable cost, c_n, and supplies them to the distributer at a unit wholesale price, w_m. The distributer wholesales these NB products to the retailer at a unit price, w_d. In turn, the retailer sells them to the end consumers at a unit retail price, p_n. Besides the NB products, the retailer also has the option for its SB. Since SBs are often acquired from perfectly competitive markets (Narasimhan & Wilcox, 1998; Tarzijn, 2004), we assume the supplier of SB is a dumb player and supplies SB products for the retailer at its unit variable production cost, c_s (Raju et al., 1995; Ru et al., 2015; Sayman et al., 2002). As a result, the retailer has the choice to distribute its SB at a unit retail price, p_s, alongside NB. For simplicity and easy comparison with widely-accepted notions (Mills, 1995; 1999; Narasimhan & Wilcox, 1998), we also assume the unit variable production cost of NB and SB are the same and equal to a constant, c. Furthermore, the unit variable sales cost of the distributer and the retailer are also assumed to be zero (Giri et al., 2016; Panda et al., 2015). Since all other parameters are independent of cost in our model, our key findings continue to hold qualitatively in the cases with different marginal production costs and non-zero sales cost.

We characterize the consumers' purchasing behavior by following Mills (1999) and assume the willingness-to-pay, v, of the continuum of consumers for the NB products is uniformly distributed over [0, 1], with unit market density, denoting that the potential market base is one. When both NB and SB are distributed by the retailer, all consumers buy one unit of the products at most, i.e. NB or SB or nothing. They make their purchasing decisions by maximizing their utilities, and we do not consider consumers' brand loyalty behavior here as Gabrielsen and Sørgard (2007) do. Given the willingness-to-pay, v, and the retail price, p_n, for the NB products, the consumer's utility is $v - p_n$ for buying NB. Given the willingness-to-pay γv and the retail price p_s for SB products, the consumer's utility is $\gamma v - p_s$ for buying SB, where $\gamma \in (0, 1)$ indicates the SB perceived quality or substitutability for NB. In other words, the SB products are usually perceived as inferior substitutes for the NB products from the perspective of the end consumers. As a consequence, when $v - p_n > 0$, the consumer will buy NB; when $\gamma v - p_s > 0$, the consumer will buy SB; when $v - p_n > 0$ and $\gamma v - p_s > 0$ both hold, the consumer will choose the product which offers the higher utility. With some algebra, we obtain that $\frac{p_n - p_s}{1-\gamma}$ is the indifferent consumer's willingness-to-pay between buying NB and SB, and $\frac{p_s}{\gamma}$ is that between buying SB and nothing. To exclude the trivial case wherein SB is never bought, we get the condition $p_s < \gamma p_n$ and $c < \gamma$. Hence, the demands for the most interesting case where both NB and SB are distributed by the retailer are

$$q_n = \begin{cases} 1 - \dfrac{p_n - p_s}{1-\gamma} & if\, p_s < \gamma p_n, \\ 1 - p_n & \text{otherwise,} \end{cases}$$
$$q_s = \begin{cases} \dfrac{\gamma p_n - p_s}{\gamma(1-\gamma)} & if\, p_s < \gamma p_n, \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

Table 1
List of notations.

Notation	Definition
γ	SB's perceived quality or substitutability for NB
c	Variable production cost of NB or SB
m, d, r	Indices for the NB manufacturer, distributer and retailer
$\overline{w_m}, w_m$	NB manufacturer's wholesale price in two- and three-echelon supply chain, respectively
w_d	distributer's wholesale price
k_d	distributer's wholesale markup, $k_d = w_d - w_m$
$\overline{p_n}, \overline{p_s}, p_n, p_s$	Retail prices of NB and SB in two- and three-echelon supply chain, respectively
$\overline{k_r}$	Retailer's retail markup in two-echelon supply chain, $\overline{k_r} = \overline{p_n} - \overline{w_m}$
k_r	Retailer's retail markup in three-echelon supply chain, $k_r = p_n - w_d$
$\overline{q_n}, \overline{q_s}, q_n, q_s$	Demands for NB and SB in two- and three-echelon supply chain, respectively
π_c	Profit of the centralized system in which all supply chain members act as one company
$\overline{\pi_m}, \pi_m$	NB-Manufacturer's profit in two- and three-echelon supply chain, respectively
π_d	distributer's profit
$\overline{\pi_r}, \pi_r$	Retailer's profit in two- and three-echelon supply chain, respectively
$\overline{\pi}$	Total profit of the whole channel in two-echelon supply chain, $\overline{\pi} = \overline{\pi_m} + \overline{\pi_r}$
π	Total profit of the whole channel in three-echelon supply chain, $\pi = \pi_m + \pi_d + \pi_r$

Explicitly, when there is no option for SB, the end consumers only make their purchasing decision by comparing the retail price p_n for NB and their willingness-to-pay v. Therefore, the demand for NB is

$$q_n = 1 - p_n. \tag{2}$$

We consider that the NB manufacturer is the leader of the channel, sequentially followed by the distributer and the retailer. Consequently, the interactions among them can be modeled as a manufacturer-led Stackelberg game. Since SB is acquired from a competitive market, the SB supplier acts as a dumb and non-strategic player. The sequence of events is illustrated in Fig. 1. All notations are formulated in Table 1. For comparison, we also examine two other cases. In the first case, all supply chain members are supposed to belong to an integrated firm and make decisions in the form of a centralized system. In the second case, we model the interaction between the NB manufacturer and the retailer in a common two-echelon supply chain. For all these three cases, we consider two scenarios: with or without the retailer's SB-introduction option.

4. Equilibrium results

4.1. Decision for centralized system

4.1.1. No SB

Suppose that all the supply chain members were vertically integrated and acted as a centralized system. When only NB is available for the retailer to distribute, the profit function of the centralized system is

$$\pi_c^o = (p_n - c)(1 - p_n). \tag{3}$$

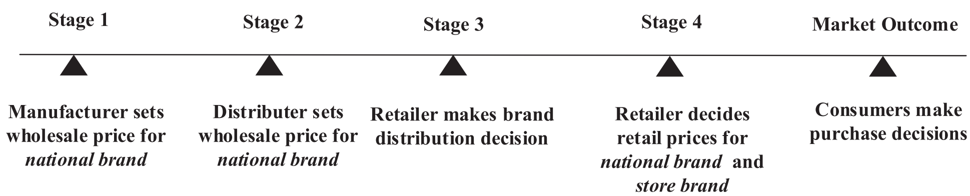

Fig. 1. Sequence of events in the three-echelon supply chain.

Fig. 2. Sequence of events in the two-echelon supply chain.

Table 2
Equilibrium Results without SB Option in Two-Echelon Supply Chain.

$\overline{w_n^o}$	$\overline{p_n^o}$	$\overline{q_n^o}$	$\overline{\pi_m^o}$	$\overline{\pi_r^o}$
$\frac{1+c}{2}$	$\frac{3+c}{4}$	$\frac{1-c}{4}$	$\frac{(1-c)^2}{8}$	$\frac{(1-c)^2}{16}$

By maximizing this profit function with respect to p_n, we can get the equilibrium results. To distinguish from the case with SB, throughout this paper, we use the superscript o to index the equilibrium results without SB. Then we have $p_n^o = (1+c)/2$, $q_n^o = (1-c)/2$, $\pi_c^o = (1-c)^2/4$.

4.1.2. With SB

When the retailer decides to introduce its SB, the profit function of the centralized system is

$$\pi_c = (p_n - c)\left(1 - \frac{p_n - p_s}{1-\gamma}\right) + (p_s - c)\frac{\gamma p_n - p_s}{\gamma(1-\gamma)}. \tag{4}$$

Maximizing this profit function with respect to p_n and p_s respectively yields $\hat{p}_n = (1+c)/2$, $\hat{p}_s = (\gamma + c)/2$. It is easy to verify that $\hat{p}_s > \gamma \hat{p}_n$ for $\gamma \in (0,1)$, indicating that an SB will never be introduced to compete with NB in the centralized supply chain. As a consequence, $\pi_c^* = \pi_c^o = (1-c)^2/4$.

4.2. Decentralized decision for two-echelon supply chain

4.2.1. No SB in two-echelon supply chain

In the decentralized supply chain, all supply chain members, the NB manufacturer and the retailer, make their decisions non-cooperatively to maximize their profits respectively. When there is no option for SB, the profit functions of the NB manufacturer and the retailer are, respectively

$$\overline{\pi_m} = (\overline{w_m} - c)(1 - \overline{p_n}), \tag{5}$$

$$\overline{\pi_r} = (\overline{p_n} - \overline{w_m})(1 - \overline{p_n}). \tag{6}$$

With backward induction to solve this manufacturer-led Stackelberg game, we obtain the equilibrium results which are summarized in Table 2.

4.2.2. With SB in two-echelon supply chain

When there is an SB introduction option for the retailer, similar to the case in the three-echelon supply chain, the sequence of events in the two-echelon supply chain with the SB option can be illustrated as in Fig. 2. As is shown in Fig. 2, given the wholesale price $\overline{w_m}$ of the NB manufacturer, the retailer has to make its brand-distribution decision and set the corresponding retail prices. There are three choices for the retailer: to distribute NB for a sufficiently low $\overline{w_m}$; to only distribute SB for a sufficiently high $\overline{w_m}$; and to distribute NB and SB simultaneously for an intermediate $\overline{w_m}$. To solve this problem with the brand-distribution option, we find the perfect solution for all three subgames by backward induction. The following lemma shows the retailer's optimal strategy. (Note that supplementary proofs of all results associated with this article can be found in the online version.)

Lemma 1. *Given the NB wholesale price w_m, the retailer's optimal retail prices for NB and SB are, respectively*

$$(\overline{p_n^*}(\overline{w_m}), \overline{p_s^*}(\overline{w_m})) = \begin{cases} (\frac{1+\overline{w_m}}{2}, N/A) & \text{if } c < \overline{w_m} < c/\gamma, \\ (\frac{1+\overline{w_m}}{2}, \frac{\gamma+c}{2}) & \text{if } c/\gamma \le \overline{w_m} \le 1+c-\gamma, \\ (N/A, \frac{\gamma+c}{2}) & \text{if } 1+c-\gamma < \overline{w_m} < 1. \end{cases} \tag{7}$$

It is never the optimal strategy for the NB manufacturer to set the NB wholesale price too high to make NB distributed by the retailer. In anticipation of the retailer's response, the manufacturer's problem is to determine an appropriate NB wholesale price to maximize its profit.

Theorem 1. *Anticipating the retailer's reaction, the optimal strategy for the NB manufacturer critically depends on γ, the SB's substitutability for NB. That is*

$$\overline{w_m^*} = \begin{cases} \frac{1+c}{2} & \text{if } c < \gamma < 2c/(1+c), \\ \frac{c}{\gamma} & \text{if } 2c/(1+c) \le \gamma \le 2c, \\ \frac{1-\gamma}{2} + c & \text{if } 2c < \gamma < 1. \end{cases} \tag{8}$$

Theorem 1 is intuitive. Since γ represents the SB's substitutability for NB, when it is low, SB will not threaten NB much. However, when γ increases to a certain high level, i.e. $2c/(1+c)$, SB will erode NB sales so much that it becomes more profitable for the NB manufacturer to induce the retailer to give up the SB introduction by reducing the NB wholesale price. Nevertheless, the NB manufacturer cannot stop the SB introduction any more when SB is too strong relative to NB. The equilibrium results of this two-echelon supply chain with SB option can be obtained by applying Theorem 1 to Lemma 1, and summarized in Table 3.

Table 3
Equilibrium results with SB option in two-echelon supply chain.

γ	$\overline{w_m^*}$	$\overline{p_n^*}$	$\overline{p_s^*}$	$\overline{q_n^*}$	$\overline{q_s^*}$	$\overline{\pi_m^*}$	$\overline{\pi_r^*}$
$\left(c, \frac{2c}{1+c}\right)$	$\frac{1+c}{2}$	$\frac{3+c}{4}$	N/A	$\frac{1-c}{4}$	N/A	$\frac{(1-c)^2}{8}$	$\frac{(1-c)^2}{16}$
$\left[\frac{2c}{1+c}, 2c\right]$	$\frac{c}{\gamma}$	$\frac{\gamma+c}{2\gamma}$	N/A	$\frac{\gamma-c}{2\gamma}$	N/A	$\frac{c(1-\gamma)(\gamma-c)}{2\gamma^2}$	$\frac{(\gamma-c)^2}{4\gamma^2}$
$(2c, 1)$	$\frac{1-\gamma}{2}+c$	$\frac{1+c}{2}+\frac{1-\gamma}{4}$	$\frac{\gamma+c}{2}$	$\frac{1}{4}$	$\frac{1}{4}-\frac{c}{2\gamma}$	$\frac{1-\gamma}{8}$	$\frac{4c^2-8c\gamma+3\gamma^2+\gamma}{16\gamma}$

Table 4
Equilibrium results without SB option in three-echelon supply chain.

w_m^o	w_d^o	p_n^o	q_n^o	π_m^o	π_d^o	π_r^o
$\frac{1+c}{2}$	$\frac{3+c}{4}$	$\frac{7+c}{8}$	$\frac{1-c}{8}$	$\frac{(1-c)^2}{16}$	$\frac{(1-c)^2}{32}$	$\frac{(1-c)^2}{64}$

4.3. Decentralized decision for three-echelon supply chain

4.3.1. No SB in three-echelon supply chain

We initially examine the setting without the SB option. The profit functions for the NB manufacturer, the distributer and the retailer, respectively, are

$$\pi_m = (w_m - c)(1 - p_n), \tag{9}$$

$$\pi_d = (w_d - w_m)(1 - p_n), \tag{10}$$

$$\pi_r = (p_n - w_d)(1 - p_n). \tag{11}$$

Solving this three-stage Stackelberg game with backward induction yields the equilibrium solution: $w_m^o = (1+c)/2$, $w_d^o = (3+c)/4$, $p_n^o = (7+c)/8$. Table 4 summarizes the equilibrium results of the game.

4.3.2. With SB in three-echelon supply chain

Now, we examine the case where the SB option is available to the retailer. In this case, the manufacturer, as a price leader, first announces its NB wholesale price w_m. The distributer, as a subsequential follower, sets its NB wholesale price w_d to the retailer. lastly, the retailer decides whether or not to introduce its SB and prices the distributed brands. We also use the backward induction to find the subgame perfect solutions for this problem. For the retailer, it also has three choices, given the distributer's wholesale price w_d of NB product, which is similar to the case in the two-echelon supply chain. The following lemma characterizes the retailer's optimal strategy on the brand-distribution decision and the retail prices.

Lemma 2. *Given the NB wholesale price w_d of the distributer and anticipating, the retailer's optimal retail prices for NB and SB are, respectively*

$$(p_n^*(w_d), p_s^*(w_d)) = \begin{cases} (\frac{1+w_d}{2}, N/A) & \text{if } c < w_d < c/\gamma, \\ (\frac{1+w_d}{2}, \frac{\gamma+c}{2}) & \text{if } c/\gamma \le w_d \le 1+c-\gamma, \\ (N/A, \frac{\gamma+c}{2}) & \text{if } 1+c-\gamma < w_d < 1. \end{cases} \tag{12}$$

Given the wholesale price w_m of the NB manufacturer, and anticipating the retailer's responding brand-distribution decision and retail prices, the distributer's problem is to choose an appropriate wholesale price w_d to maximize its profit.

Lemma 3. *Given the NB wholesale price w_m of the NB manufacturer and anticipating the retailer's response strategy, the distributer's optimal wholesale price for NB is*

$$w_d^*(w_m) = \begin{cases} \frac{1+w_m}{2} & \text{if } c < w_m < 2c/\gamma - 1, \\ \frac{c}{\gamma} & \text{if } 2c/\gamma - 1 \le w_m \le 2c/\gamma - 1 + \gamma - c, \\ \frac{1-\gamma+c+w_m}{2} & \text{if } 2c/\gamma - 1 + \gamma - c < w_m \le 1 - \gamma + c, \\ N/A & \text{if } 1 - \gamma + c < w_m < 1. \end{cases} \tag{13}$$

Finally, the NB manufacturer, in anticipation of the distributer's response, determines its wholesale price w_m to the distributer to maximize its profit. The equilibrium NB wholesale price w_m is characterized in Theorem 2.

Theorem 2. *Anticipating the distributer's response, the NB manufacturer's optimal strategy on the wholesale price w_m is*

$$w_m^* = \begin{cases} \frac{1+c}{2} & \text{if } c < \gamma < 4c/(3+c), \\ \frac{2c}{\gamma} - 1 + \gamma - c & \text{if } 4c/(3+c) \le \gamma \le 4c/3, \\ \frac{1-\gamma}{2} + c & \text{if } 4c/3 < \gamma < 1. \end{cases} \tag{14}$$

Consequently, we obtain all equilibrium results for the three-echelon supply chain with the SB-introduction option by applying Theorem 2 to Lemma 3 and to Lemma 2. All equilibrium results are summarized in Table 5.

5. Comparison and analysis

In this section, by comparing the equilibrium results of the centralized system, the two-echelon supply chain and the three-echelon supply chain, we explore how the SB introduction affects the supply-chain-player interaction and performance in the three-echelon supply chain differently from that in the two-echelon supply chain. For better comparison and observation, we plot the interaction strategies (for case with SB) of the two- and three-echelon supply chains in Figs. 3 and 4.

As illustrated in the figures, in both two- and three-echelon supply chains, there are three regimes dependent upon the SB's substitutability for NB, γ : (I) for a low γ (i.e. a weak SB), the SB option has no impact on supply chain at all; (II) for an intermediate γ (i.e. an ordinary SB), even though SB is not actually introduced, the mere potential threat of SB introduction itself can affect other supply chain members; (III) for a high γ (i.e. a competitive SB), SB cannot be prevented from entry and is eventually introduced by retailer and affects other supply chain members further more. To begin with, we compare the threshold conditions for (II) and (III) regimes between two- and three- supply chains.

Proposition 1.

(i) *Since $4c/(3+c) < 2c/(1+c)$, it shows that the three-echelon supply chain is more vulnerable to the potential threat of SB introduction than the two-echelon supply chain;*
(ii) *Since $4c/3 < 2c$, it shows that the retailer is more inclined to introduce SB in the three-echelon supply chain than the two-echelon supply chain.*

It has been widely accepted that the NB manufacturer (in a two-echelon supply chain) can manipulate NB wholesale price to

Table 5
Equilibrium results with SB option in three-echelon supply chain.

γ	w_m^*	w_d^*	p_n^*	p_s^*	q_n^*	q_s^*	π_m^*	π_d^*	π_r^*
$\left(c, \frac{4c}{3+c}\right)$	$\frac{1+c}{2}$	$\frac{3+c}{4}$	$\frac{7+c}{8}$	N/A	$\frac{1-c}{8}$	N/A	$\frac{(1-c)^2}{16}$	$\frac{(1-c)^2}{32}$	$\frac{(1-c)^2}{64}$
$\left[\frac{4c}{3+c}, \frac{4c}{3}\right]$	$\frac{2c}{\gamma} - 1 + \gamma - c$	$\frac{c}{\gamma}$	$\frac{\gamma+c}{2\gamma}$	N/A	$\frac{\gamma-c}{2\gamma}$	N/A	$\frac{(1-\gamma)(2c-\gamma)(\gamma-c)}{2\gamma^2}$	$\frac{(1-\gamma)(\gamma-c)^2}{2\gamma^2}$	$\frac{(\gamma-c)^2}{4\gamma^2}$
$\left(\frac{4c}{3}, 1\right)$	$\frac{1-\gamma}{2} + c$	$\frac{3-3\gamma}{4} + c$	$\frac{7-3\gamma}{8} + \frac{c}{2}$	$\frac{\gamma+c}{2}$	$\frac{1}{8}$	$\frac{3}{8} - \frac{c}{2\gamma}$	$\frac{1-\gamma}{16}$	$\frac{1-\gamma}{32}$	$\frac{16c^2 - 32c\gamma + 15\gamma^2 + \gamma}{64\gamma}$

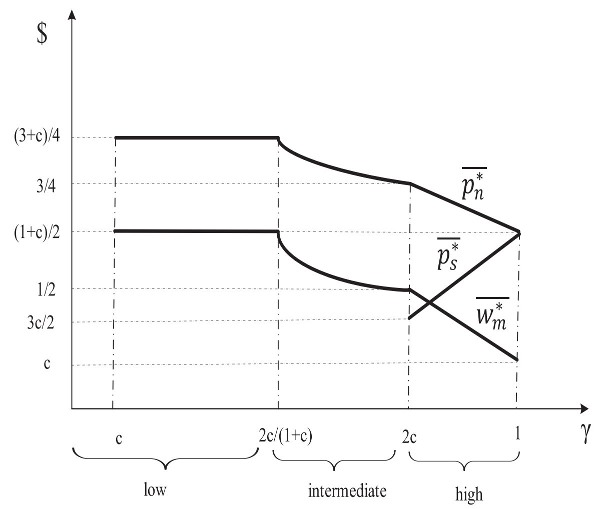

Fig. 3. Two-echelon-supply-chain players' strategies.

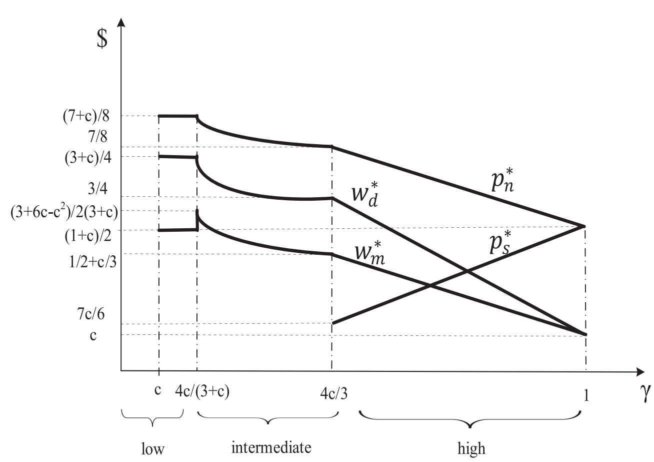

Fig. 4. Three-echelon-supply-chain players' strategies.

affect retailer's decision-making on SB introduction (Bontems et al., 1999; Fang et al., 2013; Gabrielsen & Sørgard, 2007; Mills, 1995; 1999; Narasimhan & Wilcox, 1998; Ru et al., 2015). However, in the three-echelon supply chain, the existence of the distributer makes it more complicated for the NB manufacturer to do so. The intuition behind this comes from two aspects. Firstly, the mere presence of the distributer triggers a more serious marginalization problem than in the two echelon case, ending up a higher NB retailing price (i.e. $p_n^* \geq \overline{p_n^*}$), which in turn makes a weaker SB (i.e. a lower γ) become attractive to consumers compared with in the two-echelon supply chain. Secondly, to induce the retailer to forego introducing the SB, the NB manufacturer and the distributer cannot act independently as the NB manufacturer itself does in the two-echelon case to effectively lower the NB wholesale price to the retailer (we will make a deeper analysis in the next proposition). As a result, compared with the two-echelon case, a much lower γ (i.e. $\gamma = 4c/3$) would make the NB manufacturer and the distributer stop preventing the SB introduction in the three-echelon case. Therefore, SB is more likely to pose a threat and to be actually introduced in the three-echelon supply chain.

Next, we shed light on the differences of how an SB potentially affects supply chain individual strategies between two- and three-echelon supply chains. Straightforwardly, from Fig. 4, we notice that the NB-manufacturer's strategy in the three-echelon supply chain is not a continuous function of γ, as it is in the two-echelon case. We state this interesting finding in the following proposition. Defining $A = 3(1+c)/4 - \sqrt{9 - 14c + 9c^2}/4$, $\Delta\overline{w_m} = \overline{w_m^*} - \overline{w_m^o}$, $\Delta w_m = w_m^* - w_m^o$, $\Delta\overline{k_r} = \overline{k_r^*} - \overline{k_r^o}$, $\Delta k_r = k_r^* - k_r^o$, $\Delta k_d = k_d^* - k_d^o$, then there is

Proposition 2.

(i) *When both two- and three-echelon supply chains are threatened by SB, $\Delta\overline{w_m} < 0$, however $\Delta w_m > 0$ for $4c/(3+c) \leq \gamma < A$ and $\Delta w_m < 0$ for $A < \gamma \leq 4c/3$; when SB is introduced in both two- and three-echelon supply chains, $\Delta w_m = \Delta\overline{w_m} < 0$.*
(ii) *When both two- and three-echelon supply chains are threatened by SB or with SB being introduced, $0 < \Delta\overline{k_r} < \Delta k_r$.*
(iii) *When three-echelon supply chains are threatened by SB or with SB being introduced, $\Delta k_d < 0$.*

Claim (i) challenges our received notion that the NB manufacturer must lower its NB wholesale price to deter SB entry, in a new way to the best of our knowledge. It reveals that under certain conditions (i.e. $4c/(3+c) \leq \gamma < A$) the wholesale price of the NB manufacturer may increase when with SB option. This would never happen in the two-echelon supply chain in the same context. While after SB is actually introduced, the decrease in wholesale price of the NB manufacturer is the totally the same in both supply chain cases. By and large, how the SB introduction affects the strategy of the retailer in the three-echelon supply chain is in line with the two-echelon supply chain. Nevertheless, the SB introduction in the three-echelon supply chain can offer the retailer leverage to get more NB retail markup than in the two-echelon case. Claim (iii) sates that once the retailer's SB option comes into play, the distributer's markup always decreases. Generally speaking, the existence of the distributer makes the NB manufacturer's strategic behavior quite differentiated from that in the two-echelon case. The next proposition explains how it happens.

Proposition 3. *When the retailer has the SB option and given $2c/\gamma - 1 \leq w_m \leq 2c/\gamma - 1 + \gamma - c$ from the NB manufacturer's strategy, the distributer's best responding wholesale price always equals $w_d^*(w_m) = c/\gamma$, independent of the NB manufacturer's wholesale price; otherwise, the distributer always follows the trend of the NB manufacturer's strategy when determining its wholesale price to the retailer.*

To articulate the strategic interaction between the NB manufacturer and the distributer, we plot the distributer's best response to the NB manufacturer in Fig. 5. As shown in the figure, the distributer does not always respond to the NB manufacturer consistently in the presence of SB. When the NB manufacturer sets a low wholesale price $c < w_m < 2c/\gamma - 1$, the SB-introduction option has no impact on the distributer's response (i.e. $w_d^*(w_m) = w_d^0(w_m) =$

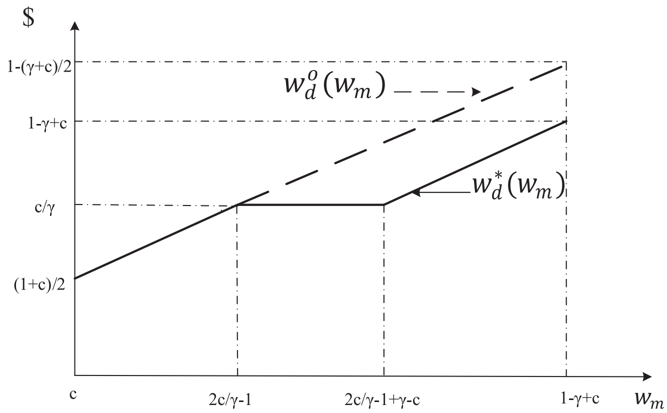

Fig. 5. Distributer's response as a function of the NB manufacturer's wholesale price.

$(1+w_m)/2)$. Interestingly, when it sets an intermediate wholesale price $2c/\gamma - 1 \le w_m \le 2c/\gamma - 1 + \gamma - c$, the distributer's response to the NB manufacturer becomes independent (i.e. $w_d^*(w_m) = c/\gamma$) due to the SB-introduction threat. In other words, the distributer would absorb all of the w_m change by itself rather than pass half of it along to the retailer in reaction to a small change in w_m, as it does when without SB. Then, when the NB-manufacturer's wholesale price increases from $(1+c)/2$ to $2c/\gamma - 1 + \gamma - c$, the distributer does not change its wholesale price accordingly. It turns out the NB manufacturer directly sets its wholesale price as high as possible, ending up with $w_m^* = 2c/\gamma - 1 + \gamma - c$. The intuition is that when the SB-introduction option begins to pose a threat to the channel, the distributer finds it more profitable to prevent SB entry if possible, and the NB manufacturer also realizes the distributer's intention. Therefore, as the leader of the channel, the NB manufacturer can take advantage of its leadership in this Stackelberg game to set w_m as high as possible, and try its best to make the distributer alone deter the retailer from SB introduction. That is why the distributer's behavior in response to the NB manufacturer is inconsistent when with SB-introduction option. As a result, when the SB's substitutability γ rises to $4c/(3+c)$ and the retailer's SB option comes to play, the NB manufacturer makes use of the distributer's inconsistent behavior and thus increase w_m directly from $(1+c)/2$ to $(3+6c-c^2)/2(3+c)$, just as shown in Fig. 4. When γ increases until $\gamma < A$ (Proposition 2), the NB manufacturer continues to set an increased wholesale price, $\Delta w_m > 0$. However, when γ keeps rising to a high level ($A < r \le 4c/3$), the distributer alone cannot deter SB introduction and the NB manufacturer starts to decrease its wholes price, $\Delta w_m < 0$. To sum up, the distributer can act as a buffer when SB introduction poses a threat to the NB manufacturer, whereby the SB introduction threat may even benefit the NB manufacturer.

As the consequence of the strategic interaction among the supply chain members, next we can compare the retail price and demand for NB and SB in different supply chains. To focus on the most interesting regime (III), in the following part we compare the equilibrium results with SB actual introduction. Defining $\Delta \overline{p_n} = \overline{p_n^*} - \overline{p_n^o}, \Delta p_n = p_n^* - p_n^o, \Delta \overline{q_n} = \overline{q_n^*} - \overline{q_n^o}, \Delta q_n = q_n^* - q_n^o,$ then there are

Proposition 4.

(i) $\Delta p_n < \Delta \overline{p_n} < 0$;
(ii) $\Delta \overline{q_n} > \Delta q_n > 0$.

In line with the finding from two-echelon supply chains (Bontems et al., 1999; Groznik & Heese, 2010; Mills, 1995; Narasimhan & Wilcox, 1998; Ru et al., 2015) that the SB introduction can alleviate the double-marginalization problem inherent in supply chains, Claim (i) further reveals that this finding still holds in the three-echelon supply chain. Moreover, it shows that SB can lessen the marginalization problem inherent in the three-echelon supply chain, surprisingly, even more than in the two-echelon case. According to Proposition 2, we can see that the greater reduction in the marginalization effect on the three-echelon supply chain comes from a lowered k_d instead of a more lowered w_m.

Claim (ii) shows that although the NB retail price is lowered more in three-echelon supply chain, the NB demand increases more in the two-echelon case. The lowered NB retail price due to the SB introduction will lead to an increased demand, although the NB demand will also be cannibalized by the SB because of brand competition. Obviously, the increase in NB demand outweighs the cannibalization effect, resulting in overall increased NB demand. However, one may question why a greater reduction in the NB retail price does not lead to the more increase in demand. The reasoning behind this is: since the NB retail price in the three-echelon supply chain is always higher than in the two-echelon case before and after SB introduced with the same retail price, SB is still more attractive than NB in the three-echelon supply chain, despite the greater reduction in the NB retail price. As a result, in the three-echelon supply chain, although SB demand is raised, NB demand increases by less than it would in the two-echelon supply chain.

Now, we examine the SB's impacts on the performance of the supply chain as a whole and its individual members. By comparing the whole channel equilibrium profit of the centralized system and those of the two decentralized systems, and defining $\Delta\overline{\pi} = \overline{\pi^*} - \overline{\pi^o}$, $\Delta\pi = \pi^* - \pi^o$, we can obtain the following proposition.

Proposition 5.

(i) $44\% \cong \dfrac{\pi^o}{\pi_c^*} < \dfrac{\overline{\pi^o}}{\pi_c^*} = 75\%$ *when* $c < \gamma < 4c/(3+c)$ *without SB-introduction option in both two- and three-echelon supply chains;*
(ii) $\pi^* < \overline{\pi^*}$ *but* $0 < \Delta\overline{\pi} < \Delta\pi$ *when* $2c < \gamma < 1$ *with SB being introduced in both two- and three-echelon supply chains.*

Claim (i) echoes with the widely-accepted wisdom that more layers in a supply chain would result in a more serious marginalization problem (Spengler, 1950; Zhang & Liu, 2013). This problem can be alleviated by SB introduction (Proposition 4), which can in turn improve the efficiency of the supply chain on the NB product. On the other hand, the SB introduction itself can also contribute to the profit of the channel as a whole. Nevertheless, how the SB introduction affects the efficiency of the three-echelon supply chain differently from the two-echelon case remains far from clear. According to Claim (ii), we show that SB can improve efficiency of the three-echelon supply chain even more than the two-echelon case, although the former's channel profit is still lower than the later's. In another word, the three-echelon supply chain can outperform the two-echelon one in terms of efficiency improvement due to SB introduction.

The reason for Claim (ii) is that, on the base of Proposition 4, the efficiency improvement of the three-echelon case on the NB product is less (a greater lowed NB retail price but a less increased NB demand) than the two-echelon case, but the SB introduction contributes more (the same SB retail price but a higher SB demand) to the three-echelon case than the two-echelon case. Obviously, the later outnumbers the former, and the efficiency of the whole channel is promoted more in the three-echelon supply chain. Summarizing, the three-echelon supply chain outperforms the two-echelon one in terms of efficiency improvement not because of more marginalization alleviation but through higher SB demand.

Next, we focus on how the SB introduction affects the performance of each individual supply chain member in both

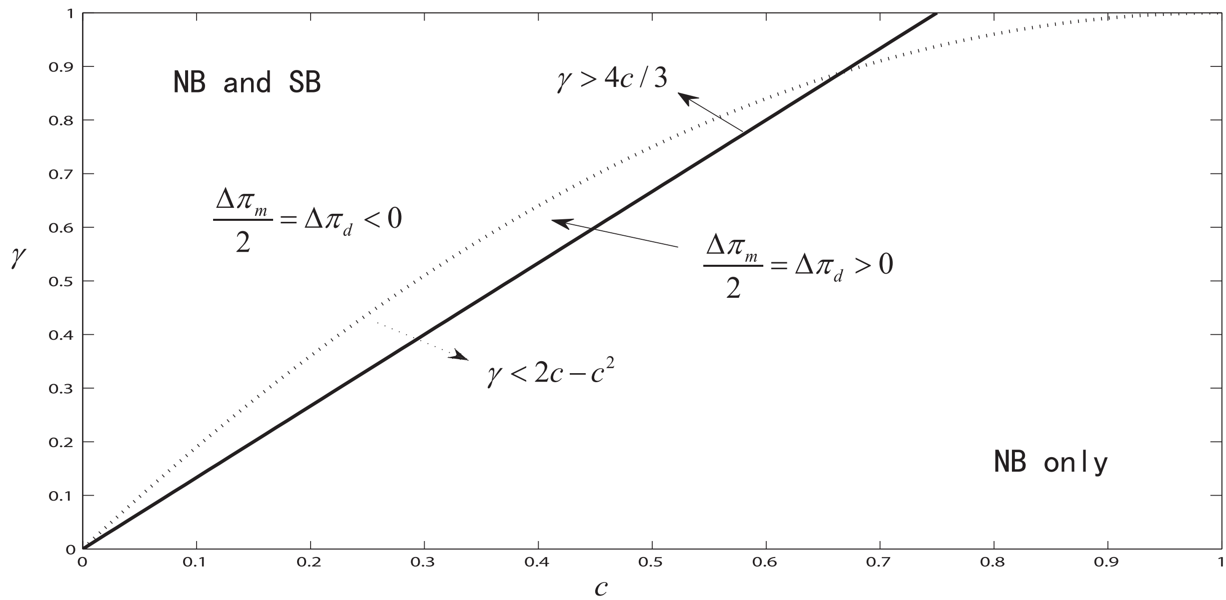

Fig. 6. SB introduction impacts on equilibrium profits of NB manufacturer and distributer.

cases, respectively, and then get the differences of two cases by comparison. Defining $\Delta\overline{\pi_r} = \overline{\pi_r^*} - \overline{\pi_r^o}$, $\Delta\overline{\pi_m} = \overline{\pi_m^*} - \overline{\pi_m^o}$, $\Delta\pi_r = \pi_r^* - \pi_r^o$, $\Delta\pi_m = \pi_m^* - \pi_m^o$, $\Delta\pi_d = \pi_d^* - \pi_d^o$, then there is

Proposition 6.

(i) *In the two-echelon supply chain, the SB introduction always benefits the retailer, but hurts the NB manufacturer, that is* $\Delta\overline{\pi_r} > 0$, $\Delta\overline{\pi_m} < 0$;

(ii) *In the three-echelon supply chain, the SB introduction can lead to a win-win situation where* $\Delta\pi_r > 0$, $\frac{\Delta\pi_m}{2} = \Delta\pi_d > 0$ *if* $4c/3 < \gamma \le 2c - c^2$. *But* $\Delta\pi_r > 0$, $\frac{\Delta\pi_m}{2} = \Delta\pi_d < 0$ *if* $2c - c^2 < \gamma < 1$.

As illustrated in Fig. 6, Proposition 6 states that the NB manufacturer and the distributer are not always hurt by the SB introduction which may even benefit all channel members. This interesting result can be explained as follows: according to Proposition 1, since $4c/3 < \gamma \le 2c - c^2 < 2c$, SB with γ satisfying $4c/3 < \gamma \le 2c - c^2$ would be introduced in the three-echelon supply chain but not in the two-echelon case. Consequently, a relatively less competitive SB will induce two effects: a lowered NB wholesale price and an increased NB demand. Since SB with $4c/3 < \gamma \le 2c - c^2$ is not too competitive, the benefit from the increased demand can compensate for the loss from the lowered wholesale price, thus making both the NB manufacturer and the distributer profit from SB introduction. But when SB becomes more competitive (i.e. $2c - c^2 < \gamma < 1$), the NB manufacturer and the distributer will suffer from a too much lowered wholesale price. This interesting finding will never happen in the two-echelon supply chain. That is why the analytical models based on the two-echelon supply chain often predict that the SB introduction always benefits the retailer but hurts the NB manufacturer. However, our finding shows that this may not be the case in the three-echelon supply chain. Even more, we find that there is a win-win situation where all channel members can benefit from SB introduction. On this point, we echo empirical studies such as Pauwels and Srinivasan (2004) and Nielsen (2014), which reveal that in practical business terms, NB manufacturers do not always suffer from the SB introduction.

The following proposition shows that how the degree to which SB introduction affects the supply chain members is differentiated. When the NB manufacturer and the distributer suffer from the SB introduction with $2c - c^2 < \gamma < 1$, we have

Proposition 7.

(i) $\Delta\overline{\pi_r} < \Delta\pi_r$;

(ii) $\Delta\pi_d = \frac{\Delta\pi_m}{2} = \frac{\Delta\overline{\pi_m}}{4}$ *for the case where the NB manufacturer and the distributer suffer from the SB introduction.*

Proposition 7 states that the retailer always benefits from the SB introduction, regardless of the channel structure. In addition, it benefits more in the three-echelon supply chain than in the two-echelon supply chain. Under the condition where both the NB manufacturer and the distributer suffer from the SB introduction in the three-echelon supply chain, they lose much less than the NB manufacturer would in the two-echelon supply chain.

6. Concluding Remarks

In this article, we investigate the impacts of an SB introduction on a three-echelon supply chain consisting of an NB manufacturer, a distributer and a retailer. In this case, the NB manufacturer is the dominant member and the retailer has an option for its SB introduction. For comparison, a centralized channel and a two-echelon supply chain with an SB introduction are also examined. We find that the interactions in the three-echelon supply chain are substantially different from those in the two-echelon case. It results in differentiated impacts of SB introduction on the performances of the supply chain members as well as the whole channel. To be specific, we obtain the following main insights.

- Compared with the two-echelon case, the three-echelon supply chain is more vulnerable to the potential threat of SB introduction and therefore SB is more inclined to be introduced.
- With SB, the strategic interaction between the NB manufacturer and the distributer may change in nature from dependence to independence. Thus the distributer can act as a buffer when the NB manufacturer is threatened by the introduction of an SB, noting meanwhile that the NB manufacturer's wholesale price might increase when SB quality is not too high.
- The three-echelon supply chain can outperform the two-echelon case in terms of efficiency improvement due to

SB introduction. However, the origin of that benefit derives from higher SB demand rather than a more dramatic marginalization-alleviation effect.

- There exists a win-win situation where the NB manufacturer, the distributer and the retailer can all benefit from SB introduction. It never happens in the two-echelon case, ceteris paribus.

To sum up, our work contributes to the existing research regarding the introduction of SBs by shedding light on how SB introduction affects a multiple-echelon supply chain. Our main insights offer another important theoretical explanation for the empirical conclusion that NB manufactures may benefit from the SB introduction, under certain conditions, especially for the FMCG filed where multiple-echelon supply chains are more often adopted. In this regard, the managerial implication is that for the executive managers in charge of NBs distributing by multiple-echelon supply chains, it is unnecessary to overreact to their retailers' SB plans, especially when SBs are not too competitive relative to their NBs. As for the managers in charge of SBs, it is much wiser and easier to introduce their SB products into categories where NBs distribute through forms involving multiple-echelon supply chains.

Although the proposed model provides some insightful results, there are limits at this stage of research and one can extend the model in several directions. First of all, just as Choi (1991) considers three possible power structures in the supply chain, i.e. Manufacturer-Stackelberg, Vertical Nash, and Retailer-Stackelberg, future research can investigate other possible leadership structures besides Manufacturer-Stackelberg, such as Retailer-Stackelberg, Vertical Nash, or even distributer-Stackelberg in a three-echelon supply chain with an SB introduction. Secondly, we assume the SB entry is a short-term decision which is made after the NB wholesale-price decision. However, in the reality, it is not uncommon that retailers set up their own plants or choose a specialized and long-term cooperation manufacturer to produce their SB, then it will be a long-term decision for the SB entry. Therefore, in the future, we will investigate whether our main results still hold and if there are any new findings to be mined from this and other scenarios. In addition, as increasing attention has begun given to the premium SBs (Chen & Dimitrov, 2015; Hara & Matsubayashi, 2017; Nenycz-Thiel & Romaniuk, 2016), investigating how the entrance of premium SBs affects multiple-echelon supply chains would be another interesting study. It would also be very interesting to examine our problem in other contexts, such as incorporating horizonal competition between NB manufacturers or retailers, or introducing channel competition between NB manufacturers' direct channel. Last, but not least, our assumption that the unit production cost of SB equals that of NB and does not change according to the perceived quality of SB, may be too rigid to correspond with reality. Hence, one can extend our research by endogenizing the perceived quality of SB and assuming a changeable production cost accordingly. Empirical studies to verify the theoretical predictions made in this study would also be a potentially fruitful direction for future research.

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Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ejor.2020.10.044.

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